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RECORDS OF THE MALARIA SURVEY OF INDIA.

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THE PRESENT STATE OF OUR KNOWLEDGE REGARDING THE TRANSMISSION OF MALARIA BY THE DIFFERENT SPECIES OF ANOPHELINE MOSQUITOES.

BY

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[October 31st, 1930]

CONTENTS.

Introduction.

IN ' A critical review of the data recorded regarding the transmission of malaria by the different species of Anopheles ' (*Ind. Med. Res. Memoir,* No. 7, 1927) the work dealing with this subject done by various observers throughout the world up to the end of the year 1926 was summarized. Since the publication of this Memoir a considerable amount of additional work on malaria transmission has been carried out in various countries. The purpose of the present paper is to review the present position with regard to our knowledge of the subject, and to bring the various records of dissections of the different species of Anopheline mosquitoes up to date.

Certain records which were omitted in Memoir No. 7 have been inserted, as also a list of corrections of some errors in the Memoir which have come to light. The author would be grateful for information as to any records of dissections which may have been omitted in this paper.

It is common to find in textbooks on Tropical Medicine, Protozoology and allied subjects, lists of 'malaria-carrying Anophelines,' which usually include all those which have ever been recorded as infected, either experimentally or in nature, even when only gut infections have been found. The great amount of research on the subject done during recent years has emphasized the fact that though very many species are possible vectors under certain conditions, yet the principal rôle is played in each locality by comparatively few, and often only one species. A list of the species considered to play the chief part in transmission in the various countries is given in the present paper, and it is thought that this may be of value to those concerned with the practical control of malaria in the field.

It is perhaps unnecessary to remark that the bare record of dissections of mosquitoes is of but little value without a knowledge of the conditions under which the observations were made, e.g., where the insects were caught, whether in human dwelling-places or in cattle sheds, etc., the time of year at which the dissections were made, whether in the 'malaria season' or not, etc., etc. It is impossible in a paper of this kind to extract all this information from the various publications recording the observations, but it is hoped that the list of references will enable those who are working on the subject to consult the original papers for further details.

It may be useful to discuss briefly the value of the various points of evidence which may be used to indicate the importance of various species of Anophelines as transmitters of malaria.

As has been remarked in an extremely valuable article by Barber, Komp and Hayne (1927), the fact that a species may be infected under laboratory conditions does not prove that it is of sanitary importance, for probably any species could be infected if one made trials enough with good gametocyte carriers. The formation of sporozoites under laboratory conditions does, however, add to the evidence of susceptibility of a species.

Epidemiological evidence may be very valuable, but here caution is needed in interpreting results. It frequently happens that the most efficient carriers are very inconspicuous, and may easily be missed unless diligently sought for by expert catchers, especially in places where the dwellings and cattle byres are made of thatch.

Evidence as regards the preference of a species for human blood is also of value, though it may be mentioned that the habits of certain species in this respect appear to differ in different localities.

As regards dissections in nature, the finding of a scanty gut infection in one insect out of a large number dissected is of but little value. The discovery of sporozoites under natural conditions is, however, of the greatest importance, and is the most valuable evidence of all as regards the part played by a particular species in transmission. Negative findings are of value when other species dissected at the same time and under the same conditions give positive results.

It is difficult to understand why some observers examine only the mid-gut. It seems to the writer that the examination of the gut only without the salivary

glands is illogical. If time is of importance it is surely much more valuable to dissect and examine the glands only, and this practice, besides disclosing the most valuable evidence as regards transmission and longevity, has the great advantage that the specimen may be very easily and rapidly made into a permanent preparation by merely making a smear and staining it with Giemsa's stain. In this way results of dissections done by laboratory assistants may be confirmed later if desired.

The interesting observation was made by Mayne (1928*b*) that *A. subpictus* is capable of acting as a host of the parasite of bird malaria. Out of 48 specimens caught in a room in which infected sparrows were kept, 2 were found with gut infections; whilst out of 96 specimens experimentally fed on infected sparrows 5 were found with gut infections, and one of these also showed sporozoites in the salivary gland. At first sight it might appear that this observation throws some doubt on the value of the results of dissections of mosquitoes under field conditions. But it should be noted that the specimens found 'naturally infected' by Mayne had no other source of blood available than the infected sparrows. Presumably it is rare for this species to feed on sparrows under natural conditions. Out of the many thousands of dissections of this species done in India, only one specimen has ever been found infected with *Plasmodia* in nature (gut only), and there is considerable doubt as to the reliability of this observation. It is not considered that Mayne's observation detracts to any appreciable extent from the value of dissections of Anophelines under natural conditions.

AMERICA.

North America.

In the eastern and southern parts of the United States *A. quadrimaculatus* is the most important carrier, whilst on the Pacific coast *A. maculipennis* is held to play a considerable part in transmission. *A. crucians* and *A. punctipennis* have both been found infected in nature, but are considered to be of minor importance.

In Mexico *A. albimanus* is the principal vector in the coastal area, whilst *A. pseudopunctipennis* and *A. quadrimaculatus* are thought to be responsible for the transmission of malaria in Mexico City. *A. pseudopunctipennis* is the chief carrier in the hills, where it is said to be the cause of endemic malaria at a height of 7,000 feet. *A. vestitipennis* and *A. argyritarsis* are thought to be of some importance in the south-eastern districts (Hoffman, 1929).

Central America, West Indies and Panama.

Throughout this region *A. albimanus* is recognized as the chief carrier, *A. tarsimaculatus* playing a secondary part. These two species are considered to be the principal vectors in Panama, though Chamberlain and Curry (1930) record that *A. bachmanni*, 'considered a dangerous malaria carrier,' has recently been discovered breeding in Gatun Lake.

In Jamaica Boyd and Aris (1929) note that whilst *A. albimanus* is the chief vector, *A. crucians* and *A. vestitipennis* may be involved in a minor degree, though they are relatively scarce and of limited distribution.

South America.

Flu (1926) states that in Dutch Guiana *A. albimanus* and *A. argyritarsis* are the chief carriers.

As regards Brazil, Boyd (1926) considered *A. argyritarsis* to be the principal carrier in the coastal region, whilst *A. tarsimaculatus* played a secondary part. He thought that *A. brasiliensis* was probably also a vector. Root (1926) however holds that the species referred to by Brazilian entomologists as '*brasiliensis*' and '*argyritarsis*' are really *albitarsis*, and does not include either of the two first mentioned species in his list of the chief malaria carriers of America (Root, 1928). Da Costa Lima (1928) considers *A. argyritarsis* to be less important than *A. albitarsis* in Brazil.

In North-Western Argentina *A. pseudopunctipennis* is the chief carrier, whilst *A. albitarsis*, *A. tarsimaculatus* and *A. argyritarsis* are said to transmit malaria in other parts of the country (Shannon and Del Ponte, 1927).

In Venezuela Benarroch (1928) states that *A. albimanus* is the principal vector, whilst *A. pseudopunctipennis* is also probably of importance, *A. argyritarsis* being less dangerous. He considers that *A. darlingi* and *A. albitarsis* are probably the chief vectors in the plains, whilst *A. tarsimaculatus*, *A. strodei* and *A. bachmanni* may also be involved.

EUROPE.

In most of the countries of Europe in which malaria occurs, *A. maculipennis* is considered to be the most important carrier of the disease.

In Italy Falleroni (1927) states that whilst there are seven species of Anophelines capable of transmitting the disease, only *A. maculipennis* need be considered from the point of view of malaria control. On the other hand, Ottolenghi and his co-workers (1927) consider that in Ferrara *A. sacharovi* (*elutus*) may be more dangerous than *A. maculipennis*.

Apfelbeck (1925) says that *A. maculipennis* is the chief vector in Bosnia and Herzegovina, whilst *A. superpictus* is probably an important carrier in South Dalmatia. Sfarcic (1927) notes that in one serious epidemic in Dalmatia, where the predominant parasite was *P. falciparum*, *A. superpictus* appeared to be the only anopheline present. Martini (1924) also considered this species to be of great importance as a vector in Macedonia. Guelmino (1928) considers that *A. maculipennis* is the sole vector in Macedonia from May to August, and that *A. superpictus* is of importance from August to mid-October.

Markoff and Moroff (1929) hold that *A. superpictus* and *A. sergentii* are important carriers in Bulgaria, on epidemiological grounds.

A large number of investigations into malarial conditions in South Russia have shown that *A. maculipennis* is by far the most important carrier in that country. Yatzenko (1927) states that *A. bifurcatus* (which is thought to be of negligible importance in Macedonia and Italy) is considered locally to be the chief vector in the mountain regions of the Crimea.

AFRICA.

North Africa.

In Algeria, *A. maculipennis* is considered to be the principal malaria carrier. *A. algeriensis* and *A. hispaniola* have both been found infected in nature, and the former species has been held responsible for the transmission of malaria at least in one locality (Sergent and Sergent, 1930).

In Tripoli, *A. mauritianus* and *A. algeriensis* have been suspected on epidemiological grounds as vectors (Franchini, 1928), although there do not appear to be any records of dissection of these species.

As regards Egypt, Kirkpatrick (1925) considers that *A. multicolor* is probably the cause of most if not all of the malaria in Egypt ' except in places where *A. sergentii*, *A. rhodesiensis** and *A. superpictus* occur.' Comyn (1927) noted that *A. pharoensis* and *A. multicolor* were the only species of anopheline captured at Moascar, near Ismailia, where there was a considerable amount of malaria among the troops. *A. pharoensis* was by far the most common. There appear to be no records of dissections of mosquitoes from Egypt.

Tropical Africa.

Throughout East, Central and West Africa, *A. gambiæ* (*costalis*) and *A. funestus* are generally recognized as being the chief malaria carriers, *A. gambiæ* being the more important of the two. Both species have repeatedly been found infected in nature, and in recent years large numbers have been dissected with positive results, notably by Schwetz, Collart and Geernick (1929) in the Belgian Congo, Garnham (1927) and Symes (1927, 1930) in Kenya Colony, Mansfield-Aders (1927) in Zanzibar, James (1929) in Uganda, Gordon and MacDonald (1930) in Sierra Leone, and Connal (1924, 1928) and Taylor (1930) in Nigeria. These two species are also considered to be the principal vectors of malaria in the Northern Transvaal and in Zululand (Ingram and de Meillon, 1929).

A. marshallii var. *moucheti* and *A. nili* have both been found infected in nature in the Belgian Congo by Schwetz and his colleagues.

In Sierra Leone, Gordon and MacDonald consider it likely that *A. smithii* plays a small but very local part in the transmission of malaria in the neighbourhood of Freetown, though there are no records of natural infections.

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* Christophers (1931) has shown that the species here called *A. rhodesiensis* is really *A. d'thali* Patton.

McHardy (1927) investigating an outbreak of malaria at Mpwapwa, Tanganyika Territory, found the only anopheline present to be *A. pitchfordi*. This species has also been suspected to be a carrier in Zululand, on epidemiological grounds. McHardy also notes *A. mauritianus* as a possible carrier in Dar-es-Salaam.

ASIA.

Asia Minor.

In Anatolia Martini (1927) states that *A. maculipennis* and *A. sacharovi* (*elutus*) probably carry malaria in the warm lowlands, whilst *A. superpictus* is the vector in the hills. *A. bifurcatus* may be of importance in one district.

In the vicinity of Aidin Sabit (1927) says that *A. bifurcatus* is the chief carrier in the spring, but as it is a comparatively wild species, transmission at this time is insignificant. *A. maculipennis* (and to some extent *A. hyrcanus* var. *sinensis* and *A. algeriensis*) are, in his opinion, responsible for malaria in the summer, and are replaced by *A. superpictus* in the late autumn, *A. superpictus* and *A. sacharovi* (*elutus*) being the most important vectors.

Transcaucasia and Central Asia.

In Transcaucasia *A. maculipennis* is thought to be the chief carrier. *A. superpictus*, *A. sacharovi* (*elutus*) and *A. bifurcatus* also occur, and may play some part in transmission.

In Central Asia *A. maculipennis* and *A. superpictus* are considered to be the most important vectors, whilst *A. sacharovi* (*elutus*) may prove to be equally dangerous (Latuishev, 1926). The rôle of *A. pulcherrimus* has not yet been determined, but it has been observed that there exist localities in which this species is abundant, but where the incidence of malaria is negligible in amount. Sawadsky (1929) has reported the finding of a female of this species with sporozoites in the salivary glands in the Golodnaja Steppe.

Palestine.

Kligler (1930) states that *A. sacharovi* (*elutus*), *A. sergentii* and *A. superpictus* are undoubtedly important carriers. These three species have all been found naturally infected in recent years. *A. bifurcatus* is of great importance in the urban and rural highland districts, which depend on cisterns for their water supply, but it is of relatively little significance in rural communities in the foot-hills and plains. *A. multicolor*, 'the salt-water species,' is of comparatively limited distribution, and is not considered to be seriously concerned in the spread of malaria. Kligler considers that *A. hyrcanus* and *A. algeriensis* which, he notes, are not house-visitors, are negligible in so far as malaria transmission in Palestine si concerned.

Arabia.

Patton (1905) found *A. gambiæ* ('*arabiensis*') naturally infected at D'thala, in the Aden Hinterland, and considered it to be the most important carrier in that region. He also suspected *A. dthali* to play some part in transmission. Gill (1916) thought that *A. culicifacies* was largely concerned in the spread of malaria in Muscat. This species is probably also of importance as a carrier in the vicinity of Aden.

Mesopotamia.

Christophers and Shortt (1921) state that *A. superpictus* is undoubtedly the carrier over most of the northern area of Mesopotamia, its presence always being associated with a high malaria incidence among troops, and a high spleen rate in native communities. The same authors state that *A. stephensi* is the chief natural carrier of malaria in Lower Mesopotamia.

India and Ceylon.

The chief malaria carriers in Northern and Peninsular India are *A. culicifacies*, *A. stephensi* and *A. listonii*. *A. culicifacies* is the most important vector in rural areas, whilst *A. stephensi* is notorious as being the great urban malaria carrier of India, it being the only malaria-carrying species capable of adapting itself to the conditions obtaining in cities.

A. maculatus and its variety *willmori* are considered to be important carriers in submontane areas, chiefly on epidemiological grounds. *A. maculatus* has been found naturally infected (gut only) by Feegrade (1927*a*) in Burma.

In Eastern India *A. minimus* is probably the most important carrier. Ramsay (1930) has shown this species to be the principal vector in the Cachar District of Assam. Iyengar (1927) considers *A. minimus* var. *varuna* to be the chief carrier in Lower Bengal. Sur and Sur (1929), as the result of their dissections under natural conditions, conclude that *A. philippinensis* plays an important part in malaria transmission in Bengal. This species has also been found naturally infected in Burma (Feegrade, 1926). *A. fuliginosus* has also been found infected in nature in Bengal and in Madras, but this species is not generally considered to play an important part in transmission.

A. ludlowii is an important carrier in the Andamans and on the coasts of Burma and Bengal. In the Andamans it is considered to be the only vector of any practical importance.

Various other species have been suspected to be carriers of malaria in India but there is no direct evidence that they play any important part in the transmission of the disease.

In Ceylon Carter (1927) considers that *A. culicifacies* and *A. listonii* are the chief carriers, whilst the position of *A. maculatus* is uncertain. The last named species, although prevalent in certain districts where malaria is severely endemic, is relatively more abundant at somewhat higher elevations (1,500 feet and over),

where the incidence of the disease is low, but where the factors of temperature and atmospheric humidity are favourable for transmission. Senior White (1920), however, is of opinion that this species is 'the malaria carrier *par excellence* of the Ceylon hill country,' on epidemiological grounds.

Siam.

Barnes (1923) records that *A. ludlowii* is a vector in the coastal region, and has been found naturally infected near Bangkok. There do not appear to be any records of dissections of other species, but *A. culicifacies*, *A. maculatus*, *A. minimus* and *A. aconitus* have been recorded from Siam, and probably play a part in the transmission of malaria.

Malaya.

A. maculatus is considered to be the principal carrier of malaria, and is the scourge of the rubber plantations. *A. umbrosus* is held to be of importance as a vector in the coconut groves. *A. aconitus* has been found naturally infected, and probably plays some part in transmission. *A. ludlowii* is a vector of importance in the coastal zone. *A. hyrcanus* and *A. fuliginosus* have also been found naturally infected, but are not generally considered to be important carriers.

Cochin-China.

A. minimus is an important carrier, and has been found naturally infected to the extent of 8 per cent (Morin, 1929).

Borel (1927) states that *A. maculatus*, *A. leucosphyrus* and *A. kochi* are suspected as being carriers on epidemiological grounds.

China and Japan.

Nauck (1928) states that *A. maculipennis* may be the chief carrier in Northern Manchuria and on the Amur. In North China *A. hyrcanus* var. *sinensis* and *A. pattoni* are considered to be probable vectors. The experimental work of Hindle and Chow (1929) has shown that both these species can transmit benign tertian malaria, but that *A. pattoni* appears to be the more favourable host. They suggest that *A. pattoni*, being the less conspicuous mosquito, may have been overlooked in places where the transmission of malaria has been attributed to *A. hyrcanus* var. *sinensis* alone.

Faust (1929) says that *A. hyrcanus* var. *sinensis* is probably the vector in Central China, where it is the only species so far recorded. In South China *A. maculatus* and *A. minimus* are probably the chief carriers. There appear to be no records of any dissections of Anophelines in nature in China.

In Formosa *A. maculatus*, *A. minimus* and *A. hyrcanus* var. *sinensis* are considered to be the chief carriers (Given, 1928). Koidzumi (1927) notes that from the evidence of experimental work *A. tessellatus* appears to be the best carrier, but that

A. maculatus is probably the most important, because it is so much more numerous.

In Central Japan, where benign tertian malaria is endemic, *A. hyrcanus* var. *sinensis* is the only anopheline present (Matsuno, 1927).

EAST INDIAN ARCHIPELAGO.

Dutch East Indies.

A. ludlowii is considered to be responsible for the greater part of the malaria in the coastal regions, whilst in the hilly part of Java *A. aconitus* and *A. maculatus* are said to be the chief vectors (Rodenwaldt, 1927). Under certain conditions *A. hyrcanus* (' *sinensis* ') and *A. kochi* can cause serious epidemics (Flu, 1926), and the former species is considered to be an important carrier in the interior of Sumatra *A. umbrosus* has been found naturally infected in Bangka. Other species which have been found infected in nature are *A. leucosphyrus*, *A. subpictus* and *A. tessellatus*. Bais (1919) considered *A. leucosphyrus* to be an important carrier, and Rodenwaldt (1927) states that *A subpictus* is probably a vector in Celebes, whilst *A. punctulatus* is considered to transmit malaria in the eastern part of the Archipelago. *A. aitkenii* (? *A. insulæ-florum*) has also been suspected as playing some part in transmission, on epidemiological grounds.

Soesilo (1929) considers *A. ludlowii* and *A. maculatus* to be the chief carriers in Nias. The same author (Soesilo, 1928), as the result of experimental infections, found that *A. subpictus* was as susceptible to benign tertian and malignant tertian infections as *A. ludlowii*, but considers that the fact that the former species prefers the blood of cattle to that of man explains why it is so rare to find it infected in nature.

Borneo and Labuan.

Stookes (1927) considers *A. ludlowii* to be the most important carrier in Sarawak, Borneo, whilst he thinks that *A. umbrosus* probably also plays a part in transmission, although there are places where the latter species is numerous and yet malaria is very slight. He suspects *A. leucosphyrus* on epidemiological grounds, and considers that the part played by *A. separatus* and *A. hyrcanus* (' *sinensis* ') needs further investigation.

Scharff (1927) holds *A. ludlowii* to be the chief vector in Labuan, though *A. umbrosus* may also be involved in transmission.

Philippine Islands.

Tiedeman (1927) states that *A. minimus* and *A. ludlowii* are the chief carriers in these islands. Manalang (1928), as the result of many dissections, conclude that *A. minimus* is the principal transmitter of infection, though it is possible that other species may be involved in certain localities.

AUSTRALASIA, MELANESIA AND POLYNESIA.

A. punctulatus and its variety *moluccensis* are vectors in New Britain, and Taylor (1927) considers that one or both of these species has probably been responsible for malaria epidemics in North Australia. There is some presumptive evidence that *A. annulipes* or *A. amictus* may transmit malaria in North Queensland. Heydon (1927), however, notes that the prevalence of endemic malaria has declined greatly on the north coast of Queensland, and considers that if *A. annulipes* or *A. amictus* are suitable vectors of the disease, its decline cannot be attributed to any scarcity of mosquitoes. If, however, as has been maintained, *A. bancrofti* is the main vector, then a decline in the numbers of this mosquito, such as seems to have occurred in certain localities, may be a factor.

De Rook (1924) has found *A. punctulatus* naturally infected in New Guinea, and considers this species to be an important vector there.

Buxton (1926) considers this species to be responsible for the malaria existing in the New Hebrides. it being the only species of anopheline recorded in the whole of Melanesia.

LIST OF THE CHIEF MALARIA-CARRYING ANOPHELINES OF THE WORLD.

I. AMERICA.

NORTH AMERICA.

United States	*quadrimaculatus* (south and east).
	maculipennis (Pacific coast).
Mexico	*albimanus* (coast).
	pseudopunctipennis } (highlands).
	quadrimaculatus } (highlands).

CENTRAL AMERICA AND WEST INDIES.

albimanus.
tarsimaculatus.

SOUTH AMERICA.

Guiana	*albimanus.*
	albitarsis.
Venezuela	*albimanus.*
	albitarsis.
Colombia	*albimanus.*
Ecuador	*albimanus.*
Brazil	*albitarsis.*
	tarsimaculatus.
Argentina	*pseudopunctipennis* (north-west).
	albitarsis (north-east).

II. EUROPE.

All countries where malaria occurs	.. *maculipennis.*
Balkans ..	.. *superpictus.*
Italy and Macedonia	.. *sacharovi* (*elutus.*)

III. AFRICA.

NORTH AFRICA.

Algeria ..	.. *maculipennis.*
	algeriensis.
Tripoli ..	.. *algeriensis.**
Egypt ..	.. *multicolor.**
	*sergentii.**
	*superpictus.**
	*dthali.**

TROPICAL AFRICA.

Throughout Tropical Africa.	*gambiæ* (*costalis*).
	funestus.
Belgian Congo ..	.. *marshallii* var. *moucheti.*
	nili.

IV. ASIA.

Asia Minor, Transcaucasia, and Central Asia	.. *maculipennis.*
	sacharovi (*elutus*).
	superpictus
Palestine ..	.. *sacharovi* (*elutus*).
	sergentii.
	superpictus.
Arabia (south) ..	.. *gambiæ.*
	*dthali.**
	*culicifacies.**
Mesopotamia ..	.. *superpictus* (north).
	stephensi (south).
India and Ceylon	.. *culicifacies.*
	stephensi.
	listonii.
	minimus.
	maculatus.
	ludlowii.
	philippinensis.†

* Suspected to be carriers on epidemiological grounds only.
† This species is considered by some observers to be an important carrier in Bengal and Burma.

Siam	*ludlowii.*
	*maculatus.**
Malaya	*maculatus.*
	umbrosus.
	ludlowii.
Cochin China	*maculatus.**
	*leucosphyrus.**
	*kochi.**
China	*hyrcanus* var. *sinensis.**
	*pattoni.**
	*maculatus.**
	*minimus.**
Formosa	*maculatus.**
	*minimus.**
	hyrcanus var. *sinensis.**
Japan ..	*hyrcanus* var. *sinensis.**

V. EAST INDIAN ARCHIPELAGO.

Dutch East Indies ..	*ludlowii.*
	maculatus.
	aconitus.
	umbrosus.
	hyrcanus ('*sinensis*').
	leucosphyrus.
	kochi (occasionally important).
	punctulatus (eastern islands).
Borneo and Labuan ..	*ludlowii.*
	*umbrosus.**
	*leucosphyrus.**
Philippine Islands ..	*minimus.*
	ludlowii.

VI. AUSTRALASIA, MELANESIA AND POLYNESIA.

New Guinea	*punctulatus.*
New Britain	*punctulatus.*
	punctulatus var. *moluccensis.*
New Hebrides	*punctulatus.**
North Queensland ..	*punctulatus.**
	*annulipes.**
	*amictus.**
	*bancrofti.**

* Suspected to be carriers on epidemiological grounds only.

RECORDS OF DISSECTIONS OF ANOPHELINE MOSQUITOES, ADDITIONAL TO THOSE RECORDED IN *INDIAN MEDICAL RESEARCH MEMOIR*, No. 7.

Natural Infections—A. aconitus.

Observer.	Locality.	Numb. Diss.	Gut. Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Gater, 1927	Malaya	419	0	0	0	..
,, ...	Petaling, Malaya ..	192	2	0	2	1
Brug and Walch, 1927 ..	Java, Dutch E. Indies ..	61	0	..	0	..
Schuurman and Schuurman, 1929.	Java, Dutch E. Indies ..	86	3	..	3	3·5
Walch and Soesilo, 1929 ..	Kota Agoeng, Sumatra, Dutch E. Indies.	452	0	..	0	..
Do	Upper Benkoelen, Sumatra, Dutch E. Indies.	290	0	..	0	..
Maung Tin, 1929 ..	Shwenyaung, Burma ..	77	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	62	0	0	0	..
Strickland, 1929	Cachar, Assam, India ..	136	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	1,661*	0	0	0	..
† Ramsay 1931	Jorhat, Assam, India ..	175	0	0	0	..

* Includes the figures given above by Strickland. † Private communication.

Experimental Infections—A. albimanus.

Parasite.	Observer.	Locality.	Numb. Diss	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
?	Benarroch, 1928 ..	Venezuela, S. America.	29	1	0	1	3·4
M. T.	Earle, 1930 ..	Porto Rico	7*	3	..	3	42·8

* None lived long enough for the formation of sporozoites.

Natural Infections—A. albimanus.

Observer.	Locality.		Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928	Venezuela, S. America.	1927	132	0	0	0	..
		1928	?	2	0	2	?

Experimental Infections—A. **apicimacula (? maculipes).**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut. Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
?	Benarroch, 1928 ..	Venezuela, S. America.	22	0	0	0	..

Natural Infections—A. **apicimacula (? maculipes).**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928	Venezuela, S. America ..	168	0	0	0	..

Experimental Infections—A. **argyritarsis.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
?	Benarroch, 1928	Venezuela, S. America.	6	0	0	0	..

Experimental Infections—A. **bachmanni.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
?	Benarroch, 1928 ..	Venezuela, S. America.	2	0	0	0	..

Natural Infections—A. **bachmanni.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928	Venezuela, S. America	75	0	0	0	..

Natural Infections—**A. barbirostris.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Stookes, 1927	Sarawak, Borneo ..	'Many'	0	0	0	..
Gater, 1927	Malaya	10	0	0	0	..
Do. ..	Petaling, Malaya ..	262	0	0	0	..
Manalang, 1928	Philippines ..	60	0	0	0	..
Carter and Jacocks, 1929 ..	Ceylon	13	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	26	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	26	0	0	0	..

Natural Infections—**A. bifurcatus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Hargreaves, 1923 ..	Taranto, Italy—					
	April	6	0	0	..	..
	May	30	0	0	..	..
	June	85	1	1	..	..
	July	24	1	1	..	..
	August ..	11	0	0	..	..
	September ..	16	1	0	..	..
	October ..	12	1	0	..	..
	November ..	7	1	0	..	..
	December ..	2	0	0	..	..
	Total ..	193	5	..	..	2·6
		193	..	2	..	1·03

Experimental Infections—**A. crucians.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Barber, Komp and Hayne, 1927.	Southern U. S. A.	53	..	..	44	83
Total, B. T. and M. T.	Do.	Do.	222	..	..	89	40·1
B. T. ..	King, W. V., 1929	Louisiana, U. S. A.	3	..	..	0	..
M. T. ..	Do. ..	Do.	16	..	..	9	56·2

Experimental Infections—**A. culicifacies.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
* B. T. ..	Carter and Jacocks, 1929.	Ceylon	7	0	0	0	..

* Attempts to infect several other species also failed.

Natural Infections—**A. culicifacies.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Carter and Jacocks, 1929 ..	Tissamaharama, Ceylon	108	0	0	0	..
	Horowupotana, Ceylon	370	0	0	0	..
	Ridigama Village, Ceylon	135	0	0	0	..
	Do. Estate 1.	230	8	4	11	3·5
	Do. Estate 2.	193	4	1	5	2·6
	Chilaw, December ..	198	4	12	15	7·6
	Do. January ..	138	1	10	11	8·7
	Karande	267	17	26	39	14·6
Carter, 1930	Chilaw, Ceylon, December 1927—September 1929.	1,897	18	45	58	3·0
	October-November, 1929	397*	10	15	22	5·5
Feegrade, 1927*a* ..	Lashio, Burma ..	57	0	0	0	..
Feegrade, 1927*b* ..	Hsipaw, Burma ..	113	1	0	1	0·8
Maung Gale, 1928 ..	Mawlaik, Burma ..	32	1	0	1	3·1
Feegrade, 1930*a* ..	Mezali, Burma ..	271	3	1	4	1·5
Feegrade, 1930*b* ..	Pwinbyu, Burma ..	41	1	0	1	2·2
Adie, 1905	Ferozepore, India ..	43	..	0	0	..
Lelean, 1911	Delhi, India ..	?	?	?	?	39·0
Hodgson, 1914	Delhi, India ..	110	3	0	3	2·7
Iyer, 1927	Bimilipatam, Madras, India.	37	4	0	4	10·3
Iyer, 1929	Udayagiri, Madras, India	52	1	1	2	3·8
King, H. H., and Krishnan, 1929*b*.	Udayagiri, Madras, India	42	4	1	4	9·5

* Out of 34 collected in October, 7 were infected (sporozoite rate 19 per cent).

Natural Infections—**A. culicifacies**—*concld.*

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
King, H. H., and Iyer, 1929	Mopad, Madras, India	297	18	4	22	7·7
Venkataraman, 1929 ..	Vizagapatam, India ..	186	3	0	3	1·6
Mayne, 1928	Saharanpur, U. P., India	2,021	2	3	5	0·2
Rao, 1929	Nandyal, Madras, India	68	1	1	2	1·5
Banerjea, 1930	Lucknow, U. P., India	60	0	0	0	..
Clyde, 1931	Banbassa, U. P., India	75	0	0	0	..
Sinton, 1925	Mani Majra, Punjab, India.	6	1	0	1	16·6
Baily, 1929	Shikarpur, Sind, India	52	6	1	7	13·4
Young and Majid, 1930 ..	Larakna, Sind, India ..	186	1	1	2	1·1
Covell and Baily, 1930 ..	Larkana, Sind, India ..	785	155	..	..	19·7
		776	..	21	..	2·7
Sur and Sur, 1929 ..	Krishnagar, Bengal, India.	168	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	3,649*	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	120	0	0	0	..

* This observer has recorded over 15,000 dissections of anophelines in Mysore, of various species, all of which have proved negative.

Natural Infections—**A. darlingi.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928 ..	Venezuela, S. America	83	0	0	0	..

Experimental Infections—**A. fuliginosus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
? ..	Sur and Sur, 1929.	Krishnagar, Bengal, India.					
		'*fuliginosus* group'	326*	..	25	25	7·6
		fuliginosus ..	58	..	6	6	10·4

* These observers state that they found that 'this group could develop all three species of the malaria parasite.'

Natural Infections—A. fuliginosus.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Manalang, 1928	Philippines ..	194	0	0	0	..
Brug and Walch, 1927 ..	Java, Dutch E. Indies	179	0	..	0	..
Walch and Soesilo, 1929 ..	Sumatra, Dutch E. Indies	31	0	..	0	..
Gater, 1927	Malaya	19	0	..	0	..
Carter and Jacocks, 1929 ..	Ceylon	17	0	..	0	..
Adie, 1905	Ferozepore, Punjab, India.	148	..	1	1	0·7
Hodgson, 1914	Delhi, India ..	131	0	0	0	..
Graham, 1911	Naini Tal, U. P., India	50	0	0	0	..
Mayne, 1928 .. .	Saharanpur, U. P., India	875	0	0	0	..
Banerjea, 1930 .. .	Lucknow, U. P., India	78	0	0	0	..
Clyde, 1931	Banbassa, U. P., India	350	..	0	0	..
Iyengar, 1928	Hooghly Dist., Bengal, India.	125	..	1	1	0·8
Sur and Sur, 1929 ..	Krishnagar, Bengal, India.					
	'*fuliginosus* group' ..	7,029	..	30	30	0·4
	fuliginosus	3,944	..	6	6	0·15
,, ...	Birnagar, Bengal, India	787	..	1	1	0·15
King and Krishnan, 1929 ..	Udayagiri, Madras, India	8	1	0	1	12·5
Sweet, 1929-30	Mysore, S. India ..	519	0	0	0	..
Maung Tin, 1929 ..	Shwenyaung, Burma ..	28	0	0	0	..
Strickland, 1929 ..	Cachar, Assam, India ..	51	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	335*	0	0	0	..

* Ramsay's figures include those of Strickland, above.

Experimental Infections—A. funestus.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
M. T. ..	Daniels, 1900	Central Africa ..	220*	0	0	0	..

* Fed on patients with very scanty infections.

Natural Infections—A. **funestus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Daniels, 1900	Central Africa ..	1,500	0	0	0	..
Wood, 1915	Sierra Leone, W. Africa	100	..	11	11	11·0
Taylor A. W., 1930 ..	Nigeria, W. Africa ..	1,260	79	..	..	6·3
		1,260	..	44	..	3·5
Schwetz, Collart and Geernick, 1929.	Belgian Congo, C. Africa.	191	6	..	..	3·1
		191	..	8	..	4·2
Mansfield-Aders, 1927 ..	Zanzibar, E. Africa ..	1,167	..	80	80	7·0
Kauntze, 1926	Kenya Colony, E. Africa.	?	2	..	2*	?
Symes, 1927	Kisumu, Kenya Colony, E. Africa.	?	2	..	2*	?
Garnham, 1927	Kisumu, Kenya Colony, E. Africa.					
	April—October ..	286	3	..	..	1·1
	June—January .	819	..	2	..	0·24
McHardy, 1928	Dar-es-Salaam, Tanganyika Territory, E. Africa	165	..	17	17	11·5
Symes, 1930 .. .	Kitale, Kenya Colony, E. Africa	15	..	1	1	6·6
James, 1929 .. .	Kampala, Uganda, E. Africa.	121	16	..	..	13·2
		36	..	1	..	2·8
Hancock, 1930	Uganda, E. Africa ..	?	‘infections’			?

* These probably refer to the same dissections. It seems probable, also, that they have been included in Garnham's figures, below.

Experimental Infections—A. **gambiae (‘costalis’).**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
M. T. ..	Gordon and MacDonald, 1930.	Sierra Leone, W. Africa.	21	..	3	3	14·3

Natural Infections—**A. gambiæ ('costalis').**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Wood, 1915	Sierra Leone, W. Africa	91	..	8	8	8·8
Gordon and MacDonald, 1930	Sierra Leone, W. Africa	21	..	2	2	9·5
Connal, 1924	Nigeria, W. Africa ..	198	29	19	32	16·0
Connal, 1928	Nigeria, W. Africa ..	693	2	5	5	0·7
Taylor A. W., 1930 ..	Nigeria, W. Africa ..	1,936	238	..	..	11·8
		1,936	..	144	..	7·4
Schwetz, Collart and Geernick, 1929.	Belgian Congo, C. Africa	992	83	..	..	8·4
		922	..	114	..	11·5
Mansfield-Aders, 1927 ..	Zanzibar, E. Africa ..	1,833	..	134	134	7·7
Kauntze, 1926	Nairobi, Kenya Colony, E. Africa.	338*	2	2	4	1·2
Symes, 1927	Nairobi, Kenya Colony, E. Africa.	338*	2	2	4	1·2
Garnham, 1929	Kisumu, Kenya Colony, E. Africa.					
	April—October ..	133	0	..	0	..
	June—January ..	148	..	1	1	0·7
McHardy, 1928	Dar-es-Salaam, Tanganyika Territory, E. Africa.	127	..	26	26	25·7
Symes, 1930	Kitale, Kenya Colony, E. Africa.	90	..	7	7	7·2
James, 1929	Uganda, E Africa ..	335	37	..	..	11·0
		119	..	7	..	5·9
Hancock, 1930	Uganda, E. Africa ..	?	'infections'			?
Ingram and de Meillon, 1929	Rustenburg, S, Africa ..	?	..	1	..	?

* These two sets of figures probably refer to the same dissections.

Natural Infections—**A. grabhamii.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Greene, 1921-23	Porto Rico ..	351	2	0	2	0·57

Experimental Infections—A. **hyrcanus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	MacArthur, 1929 (*sinensis*).	Shantung, China	?	'easily infected.'			
B. T. ..	Hindle and Chow, 1929 (*sinensis*).	Shanghai, China	121	2	19	21	17·3
? ..	Sur and Sur, 1929 (*nigerrimus*).	Krishnagar, Bengal, India.	53	0	0	0	..
B. T. ..	Carter and Jacocks, 1929.	Ceylon	15*	0	0	0	..

* Attempts to infect several other species also failed.

Natural Infections—A. **hyrcanus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Manalang, 1928	Philippines ..	77	0	0	0	..
Bloch, 1921-22 ('*sinensis*')	Banka, Dutch E Indies	625	3	..	3	0·5
de Rook, 1923 ('*sinensis*')	Sumatra, Dutch E. Indies.	663	8	..	8	1·2
Walch and Soesilo, 1929 (*sinensis*).	Kota Agoeng, Sumatra	835	28	..	28	3·3
Do.	Martapoera, Sumatra ..	246	1	..	1	0·5
Do.	Upper Benkoelen, Sumatra.	917	4	..	4	0·4
Gater, 1927 (*nigerrimus*) ..	Malaya	84	0	0	0	..
Carter and Jacocks, 1929 ..	Ceylon	33	0	0	0	..
Sweet, 1929-30 (*nigerrimus*)	Mysore, S. India ..	21	0	0	0	..
Maung Tin, 1929 (*nigerrimus*)	Shwenyaung, Burma ..	15	0	0	0	..
Sur and Sur, 1929 (*nigerrimus*)	Krishnagar, Bengal, India.	190	..	0	0	..
	Birnagar, Bengal ..	74	..	0	0	..
Strickland, 1929 (*nigerrimus*)	Cachar, Assam, India	1,757	0	0	0	..
Ramsay, 1930 (*nigerrimus*) ..	Cachar, Assam, India ..	5,641*	0	0	0	..
† Ramsay, 1931 (*nigerrimus*)	Jorhat, Assam, India ..	209	0	0	0	..

* Ramsay's figures include those of Strickland, above.

† Private communication.

Experimental Infections—A. jamesii.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Carter and Jacocks, 1929.	Ceylon	1*	0	0	0	..

* Attempts to infect several other species were also unsuccessful.

Natural Infections—A. jamesii.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Carter and Jacocks, 1929 ..	Ceylon	16	0	0	0	..
Feegrade, 1926	Bhamo, Burma ..	35	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	216	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	162	0	0	0	..

Natural Infections—A. jeyporiensis.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Sweet, 1929-30	Mysore, S. India ..	1,789	0	0	0	..
Strickland, 1929 ..	Cachar, Assam, India ..	125	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	888*	0	0	0	..

* Ramsay's figures include those of Strickland, above.

Natural Infections—A. karwari.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Manalang, 1928	Philippines ..	27	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	49	0	0	0	..
Strickland, 1929 ..	Cachar, Assam, India ..	1,697	1*	0	1	0·06
Ramsay, 1930	Cachar, Assam, India ..	9,242†	0	0	0	..

* Out of 125 dissected in July.

† Ramsay's figures include those of Strickland, above, but it will be noted that he does not show any of this species found infected. Dr. Ramsay informs me in a private communication that soon after the commencement of his investigations in 1927 he observed what he then believed to be an early gut infection in one specimen, but that subsequent experience convinced him that this was in reality an artefact.

Natural Infections—A. kochi.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Gater, 1927	Malaya	19	0	0	0	..
Walch and Soesilo, 1929 ..	Kota Agoeng, Sumatra, Dutch E. Indies.	23	0	..	0	..
Do.	Martapoera, Sumatra	215	0	..	0	..
Do.	Upper Benkoelen, Sumatra.	523	0	..	0	..
Soesilo, 1929	Nias, Dutch E. Indies ..	230	0	..	0	..
Strickland, 1929 ..	Cachar, Assam, India ..	535	1	0	1	0·18
Ramsay, 1930	Cachar, Assam, India,					
	January ..	126	0	0	0	..
	February ..	174	0	0	0	..
	March .	246	0	0	0	..
	April	289	0	0	0	..
	May	209	0	0	0	..
	June	131	0	0	0	..
	July	77	2	0	2	2·6
	August ..	140	0	0	0	..
	September ..	64	0	0	0	..
	October ..	104	0	0	0	..
	November ..	287	0	0	0	..
	December ..	266	0	0	0	..
	TOTAL ..	9,212*	2	0	2	0·02

* Ramsay's figures include those of Strickland, above.

Natural Infections—A. leucosphyrus.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Strickland, 1929	Cachar, Assam, India ..	36	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	175*	0	0	0	..

* Ramsay's figures include those of Strickland, above.

Experimental Infections—A. listonii.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Carter and Jacocks, 1929.	Ceylon ..	5*	0	0	0	..

* Attempts to infect several other species were also unsuccessful.

Natural Infections—A. listonii.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Carter and Jacocks, 1929 ..	Ceylon	25	0	0	0	..
Carter, 1930	Ceylon	14	0	0	0	..
King, H. H., and Iyer, 1929 ..	Mopad, Madras, India ..	77	3	0	3	3·9
Sweet, 1929-30	Mysore, S. India ..	1,142	0	0	0	..
Hyde, 1931	Banbassa, U. P., India	460	0	0	0	..

Experimental Infections—A. ludlowii.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Q. ..	Hylkema, 1920	Belawan, Sumatra, Dutch E. Indies.	117*	25	..	25	21·4
B. T. ..	Soesilo, 1928 ..	Batavia, Dutch E. Indies.	9	7	2	8	88·8
M. T. ..	Do. ..	Do.	23	20	7	20	86·9

* In some batches, 50 per cent of the mosquitoes become infected.

Natural Infections—**A. ludlowii.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Stookes, 1927	Sarawak, Borneo ..	22	3	0	3	13·6
Hylkema, 1920	Belawan Sumatra, Dutch E. Indies.	720	26	..	26	3·6
Essed, 1929	Java, Dutch E. Indies ..	49	1	..	1	2·0
Schuurman and Schuurman, 1929.	Java, Dutch E. Indies	30	2	..	2	6·6
Soesilo, 1929	Nias, Dutch E. Indies, 1926 ..	256	7	..	6	2·7
	1927 ..	45	3	..	3	6·6

Experimental Infections—**A. maculatus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Green, 1929 ..	Malaya	141	..	..	22*	15
M. T. ..	Do. ..	Do.	514	..	..	112*	22
Q ..	Do. ..	Do.	159	3	0	3	2
B. T. ..	Carter and Jacocks, 1929.	Ceylon	1†	0	0	0	..

* Green notes that there were both gut and gland infections with B. T. and M. T. Among infected batches of mosquitoes the sporozoite rate was 62·5 per cent with B. T and 74·3 per cent with M. T., whereas no sporozoite formation took place with Q. He concludes that *A. maculatus* can transmit B. T. and M. T. malaria, but that its ability to transmit Quartan has not been proved.

† Attempts to infect several other species were also unsuccessful.

Natural Infections—A. **maculatus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Bloch, 1921-22	Banka, Dutch E. Indies	369	5	..	5	1·4
Walch and Soesilo, 1929 ..	Sumatra, Dutch E. Indies	51	0	..	0	..
Do.	Java, Dutch E. Indies (3,900 feet).	135	4	..	4	3·0
Feegrade, 1927*a*	Lashio, Burma ..	13	1	0	1	7·6
Strickland, 1929	Cachar, Assam, India ..	147	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	3,374*	0	0	0	..
Clyde, 1931	Banbassa, U. P., India	60	0	0	0	..

* Ramsay's figures include those given by Strickland, above.

Natural Infections—A. **maculipalpis** var. **indiensis.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Mayne, 1928	Saharanpur, U. P., India	258	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	22	0	0	0	..
Clyde, 1931	Banbassa, U. P., India	35	0	0	0	..

Experimental Infections—A. **maculipennis.***

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Ottolenghi and Rosetti, 1928.	Italy	?	..	..	..	35–50†
B. T. ..	Simanin, 1928 ..	Russia	11‡	..	..	9	81·8
M. T. ..	Do.	Do.	87‡	..	..	50	57·4

* A large number of other experiments have been recorded in which this species has been used for the experimental transmission of malaria in connection with the treatment of general paralysis of the insane.

† The mosquitoes remained infected for 4 months, at a temperature of 37·4°F.

‡ The patients from which the mosquitoes were infected had been taking quinine.

Natural Infections—A. maculipennis.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Gosio, in Mannaberg, 1905 ..	Tuscany, Italy,					
	April ..	5	0	0	0	..
	May ..	169	0	0	0	..
	June ..	144	0	0	0	..
	July ..	157	1	1	?	..
	August ..	107	3	2	?	..
	September ..	117	1	1	?	..
	October ..	131	22	0	22	..
	TOTAL ..	830	27	..	..	3·2
		830	..	4	..	0·48
Hargreaves, 1923 ..	Taranto, Italy,					
	April ..	18	0	0	0	..
	May ..	18	0	0	0	..
	June ..	93	2	1	?	..
	July ..	210	12	2	?	..
	August ..	210	23	1	?	..
	September ..	133	16	2	?	..
	October ..	56	5	2	?	..
	November ..	10	1	0	1	..
	December ..	8	0	0	0	..
	TOTAL ..	756	59	..	..	7·81
		756	..	8	..	1·06
Pecori and Escalar, 1929 ..	Roman Campagna, Italy	1,755	?	?	8	0·5
Reinhard and Dolbeshkin, 1927.	Ekaterinoslav, Russia ..	6,294*	..	..	..	..
Guelmino, 1928	Macedonia	2,000†	0	0	0	..

* These were mostly *maculipennis*, caught in 1924-25. In 1924 20 per cent of those caught in houses were infected.

† These were hibernating mosquitoes, caught during the winter.

Natural Infections—A. marshallii var. moucheti.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Schwetz, Collart and Geernick, 1929.	Belgian Congo, C. Africa.	154	7	..	..	4·5
		154	..	7	..	4·5

Natural Infections—**A. mauritianus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Taylor, 1930	Nigeria, W. Africa ..	46	0	0	0	..

Natural Infections—**A. minimus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Manalang, 1928	Philippines ..	2,283 2,283	19 ..	.. 8	.. ..	0·83 0·35
Manalang, 1931	Philippines ..	21,707*	181	117	298	1·4
Morin, 1929	Cochin-China ..	63	2	3	5	8·0
Feegrade, 1927*a* ..	Lashio, Burma ..	265	?	?	6	2·6
Feegrade, 1927*b* ..	Hsipaw, Burma ..	350	9	0	9	2·57
Maung Tin, 1929 ..	Shwenyaung, Burma	784	?	?	12	1·5
	,, 'var. new'	9	?	?	3	33·0
Iyengar, 1928	Hooghly Dt., Bengal, India (*varuna*) ..	25	..	1	1	4·0
Sur and Sur, 1929 ..	Krishnagar, Bengal, India	143	..	0	0	..
	Birnagar, Bengal ..	25	..	0	0	..
Strickland, 1929 ..	Cachar, Assam, India ('*funestus*') ..	1,489	39	19	58	3·9
Ramsay, 1930	Cachar, Assam, India,					
	January ..	244	0	0	0	..
	February ..	139	0	0	0	..
	March ..	124	0	0	0	..
	April ..	233	1	0	1	0·4
	May ..	350	3	3	6	1·7
	June ..	417	10	7	17	4·1
	July ..	516	7	2	9	1·7
	August ..	212	8	2	10	4·7
	September ..	109	3	1	4	3·7
	October ..	331	6	1	7	2·1
	November ..	647	13	10	23	3·5
	December ..	552	8	1	9	1·6
	TOTAL ..	3,847†	59	27	86	2·2
Ramsay, 1931‡	Jorhat, Assam, India ..	1,221	26	38	64	5·3
Clyde, 1931	Banbassa, U. P., India	550	0	0	0	..

* These figures include those of Manalang, 1928.

† Ramsay's figures include those given by Strickland, above.

‡ Private communication. Over 900 anophelines of other species dissected at the same time were negative.

Natural Infections—A. nili.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Schwetz, Collart and Geernick, 1929.	Belgian Congo, C. Africa	132	13	..	..	10·0
		132	..	7	..	5·3
Taylor, 1930	Nigeria, W. Africa ..	9	0	0	0	..

Experimental Infections—A. pallidus.

Parasite.	Observer.	Locality.	Numb Diss.	Gut. Inf.	Gld Inf.	Tot. Inf.	Percent. Inf.
? ..	Sur and Sur, 1929	Krishnagar, Bengal, India.	23	.	3	3	13·0

Natural Infections—A. pallidus.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Sur and Sur, 1919 ..	Krishnagar, Bengal, India	1,236	..	3	3	0·24
	Birnagar, Bengal .	234	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	82	0	0	0	..

Experimental Infections—A. pattoni.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Hindle and Chow, 1929.	Shantung, China	11	1	8	9	81·8

Natural Infections—A. pharoensis.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Taylor, 1930	Nigeria, W. Africa ..	205	0	0	0	..

Experimental Infections—A. **philippinensis.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
? ..	Sur and Sur, 1929	Krishnagar, Bengal, India.	7	..	0	0	..

Natural Infections—A. **philippinensis.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Feegrade, 1926	Bhamo, Burma ..	189	2	1	3	1·6
Sur, P., 1928	Bengal, India ..	223	3	5	7	3·1
Sur and Sur, 1929 ..	Krishnagar Bengal, India.	770	..	15	15	2·0*
	Birnagar, Bengal ..	458	..	7	7	1·5
Strickland, 1929	Cachar, Assam, India ..	2,410	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	6,895†	0	0	0	..
‡Ramsay, 1931	Jorhat, Assam, India ..	229	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	17	0	0	0	..

* The sporozoite rate was 4·1 per cent for the month of November 1927 (96 dissections), and 4·5 per cent for September 1928 (88 dissections).

† Ramsay's figures include those of Strickland, given above.

‡ Private communication.

Experimental Infections—A. **pseudopunctipennis.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Barber, Komp and Hayne, 1927.	Southern, U. S. A.	8	?	?	1	12·5
B. T. ..	Davis and Shannon, 1928.	Argentina, S. America.	6*	0	0	0	..
M. T. ..	Do. ..	Do.	8*	3	..	3	37·5
Q. ..	Do. ..	Do.	3	0	0	0	..

* The patients in these experiments had taken quinine.

Natural Infections—A. pseudopunctipennis.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928	Venezuela, S. America	103	0	0	0	..
Davis and Shannon, 1928 ..	Argentina, S. America ..	369	8	0	8	2·2

Experimental Infections—**A. pulcherrimus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Averbukh, 1928	Kazakstan, Central Asia.	?	Oocysts and sporozoites.		..	?

Natural Infections—**A. pulcherrimus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf	Tot. Inf.	Percent. Inf.
Sawadsky, 1929	Central Asia ..	?	..	1	1	?
Young and Majid, 1930 ..	Larkana, Sind, India ..	49	0	0	0	..
Covell and Baily, 1930 .	Larkana, Sind, India ..	453	5	0	5	1·1

Experimental Infections—**A. punctimacula.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld Inf.	Tot. Inf.	Percent. Inf.
? ..	Benarroch, 1928 ..	Venezuela, S. America.	1	0	0	0	..

Natural Infections—**A. punctimacula.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percen. Inf.
Benarroch, 1928	Venezuela, S. America..	56	0	0	0	..

Experimental Infections—**A. punctipennis.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Barber, Komp and Hayne, 1927.	Southern, U. S. A.	7	..	..	7	100·0
M. T. ..	Do. ..	Do.	8	..	..	2	25·0
Total B. T. and M. T.	Do. ..	Do.	28	..	..	9	32·1
B. T. ..	St. John, 1928 ..	U. S. A.	50	6	3	7	14·0
B. T. ..	King, W. V., 1929	Louisiana, U. S. A.	12	..	..	6	50·0
M. T. ..	Do. ..	Do.	29	..	..	7	24·1

Experimental Infections—**A. quadrimaculatus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Barber, Komp and and Hayne, 1927.	Southern, U. S. A.	43	..	..	23	53·5
M. T. ..	Do. ..	Do.	8	..	..	0	..
Total B. T. and M. T.	Do. ..	Do.	299	..	..	105	35·1
B. T. ..	King, W. V., 1929	Louisiana, U. S. A.	51	..	..	19	37·2
M. T. ..	Do. ..	Do.	15	..	..	4	26·6

Natural Infections—**A. quadrimaculatus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
King, W. V., 1929 ..	Louisiana, U. S. A. ..	114*	..	..	22	19·0

* From houses in which cases of malaria had occurred, or in which infected mosquitoes had previously been found.

Natural Infections—**A. ramsayi (pseudojamesi).**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Sur and Sur, 1929 ..	Krishnagar, Bengal, India.	123	..	0	0	..
Do.	Birnagar, Bengal ..	99	..	0	0	..
Strickland, 1929 ..	Cachar, Assam, India ..	256	0	1	1	0·4
Ramsay, 1930	Cachar, Assam, India ..	287*	0	1	1	0·36

* Ramsay's figures include those given by Strickland, above The infected specimen was one out of 27 dissected in June 1927, and is the same insect as that referred to in *Ind. Med. Res. Mem.*, No. 7, p. 74.

Experimental Infections—**A. rhodesiensis.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
M. T. ..	Gordon and MacDonald, 1930.	Sierra Leone, W. Africa.	18	0	1	1	5·5
Q.	Do.	Do.	7	0	0	0	..

Natural Infections—**A. rhodesiensis.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Wood, 1915	Sierra Leone, W. Africa	37	..	1	1	2·7

Experimental Infections—A. rondoni.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Davis and Shannon, 1928.	Argentina, S. America.	7*	0	0	0	..
M. T. ..	Do	Do	5*	0	0	0	..
Q.	Do.	Do.	9	0	0	0	..

* In these experiments the patients had taken quinine. Out of 8 specimens of *A. pseudo-punctipennis* fed on the patient with M. T., 5 became infected.

Natural Infections—A. rondoni.

Observer.	Locality.	Numb. Diss	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Davis and Shannon, 1928 .	Argentina, S. America ..	88	0	0	0	..

Natural Infections—A. rufipes.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Taylor, A. W., 1930 ..	Nigeria, W. Africa ..	24	0	0	0	..

Experimental Infections—A. sacharovi (elutus).

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Ottolenghi and Rossetti, 1928.	Italy	?	.	..	..	30–50*
M. T. ..	Kligler, 1930 ..	Palestine	20†	12	..	12	60

* The mosquitoes used in this experiment remained infected for 4 months at a temperature of 37·4°F.

† The patients had taken quinine. Eight other mosquitoes (? species) were dissected and found negative.

Natural Infections—**A. sacharovi (elutus).**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Kligler and Liebman, 1929 ..	Palestine,					
	Stables—					
	June—September ..	76	0	0	0	..
	October—December ..	122	2	3	4	3·3
	Houses—					
	June—September ..	257	9	7	14	5·4
	October—December ..	256	4	0	4	1·5
Do.	Tlell, Palestine, November	85	0	0	0	..
	Yessod ,, ,, ..	102	1	0	1	1·0
	Sbed ,, ,, ..	93	3	2	3	3·2
	Rosh Pinah ,, December	95	2	2	4	4·2
Kligler, 1930	Palestine					
	January ..	235	..	..	2	0·9
	February ..	122	..	..	0	..
	March .	71	..	..	1	1·4
	April ..	105	..	..	0	..
	May ..	218	..	..	0	..
	June ..	299	..	..	5	1·7
	July ..	244	..	..	3	1·2
	August ..	230	..	..	5	2·2
	September ..	66	..	..	2	3·0
	October ..	272	..	..	5	1·8
	November ..	263	..	..	2	0·7
	December ..	260	..	..	4	2·3
	TOTAL ..	2,385*	..	..	29	1·2

* It seems probable that Kligler's figures include those of Kligler and Liebman.

Experimental Infections—A. **separatus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Pendlebury, 1926	Malaya	27	0	0	0	..
M. T. ..	"	"	34	0	0	0	..
Q.	"	"	8	0	0	0	..

Experimental Infections—A. **sergentii.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
M. T. ..	Kligler, 1930 ..	Palestine	13*	7	..	7	53·8

* The patients had taken quinine. Eight other mosquitoes (? species) were dissected and found negative.

Natural Infections—A. **sergentii.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Kligler, 1930	Palestine	195	?	?	1	0·5

Experimental Infections—A. **smithii.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
M. T. ..	Gordon and Mac-Donald, 1930.	Sierra Leone, W. Africa.	6	..	2	2	40·0

Natural Infections—A. **squamosus**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Taylor, 1930	Nigeria, W. Africa ..	83	0	0	0	..

Experimental Infections—A. stephensi.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
?	Sur and Sur, 1929	Krishnagar, Bengal, India.	12	..	1	1	8·3

Natural Infections—A. stephensi.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Hodgson, 1914	Delhi, India ..	110	2	0	2	1·8
Mayne, 1928	Saharanpur, U. P., India	248	0	0	0	..
Banerjea, 1930	Lucknow, U. P., India	75	7	5	7	9·3
Covell, 1928	Bombay, India ..	671	17	12	28	4·2
Sur and Sur, 1929 ..	Krishnagar, Bengal, India.	21	0	0	0	..
King, H. H. and Iyer, 1929 ..	Mopad, Madras, India	166	9	1	10	5·4
Sweet, 1929-30	Mysore, S. India ..	1,498	0	0	0	..

Experimental Infections—A. strodei.

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
? ..	Benarroch, 1928 ..	Venezuela, S. America.	5	0	0	0	.

Natural Infections—A. strodei.

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928 ..	Venezuela, S. America	22	0	0	0	..

Experimental Infections—**A. subpictus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
B. T. ..	Soesilo, 1928 ..	Batavia, Dutch E. Indies.	26*	21	8	23	88·5
M. T. ..	Do. ..	Do.	49*	38	21	42	85·7
M. T. ..	Do. ..	Do.	15†	12	3	12	80·0
B. T. ..	Carter and Jacocks, 1929.	Ceylon	1‡	0	0	0	..

* Bred from salt-water fish-ponds.
† Bred from fresh-water pools.
‡ Attempts to infect several other species were also unsuccessful.

Natural Infections—**A. subpictus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Manalang, 1928	Philippines ..	41	0	0	0	..
Tiedeman, 1927 (*malayensis*)..	Do. ..	360	0	..	0	..
		50	..	0	..	..
Brug and Walch, 1927 ..	Java, Dutch E. Indies	221	1	..	1	0·4
Carter and Jacocks, 1929 ..	Ceylon	288	0	0	0	..
Carter, 1930	Do.	399	0	0	0	..
James, 1902	Calcutta, India ..	324*	0	0	0	..
Sur and Sur, 1929 ..	Krishnagar, Bengal, India.	1,302	0	0	0	..
Hodgson, 1924	Delhi, India ..	84	0	0	0	..
Mayne, 1928	Saharanpur, U. P., India.	1,650	0	0	0	..
Banerjea, 1930	Lucknow, U. P., India	89	0	0	0	..
Iyer, 1927	Bimlipatam, Madras, India.	316	0	0	0	..
King, H. H. and Krishnan, 1929*a*.	Mopad, Madras, India	122	0	0	0	..
King, H. H. and Krishnan, 1929*b*.	Udayagiri, Madras, India	60	0	0	0	..
Iyer, 1929	Do.	53	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	3,935	0	0	0	..

* Probably this species.

Experimental Infections—**A. superpictus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
M. T. ..	Kligler, 1930 ..	Palestine.	2*	1	1	2	100

* The patients had had quinine. Eight other mosquitoes (? species) were dissected and found negative.

Natural Infections—**A. superpictus.**

Observer.	Locality	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Guelmino, 1928	Macedonia .. .	2,000*	..	..	0	..
Kligler and Liebman, 1929 .	Palestine,					
	Stables—					
	July—September .	179	0	2	2	1·1
	October–December ..	12	1	0	1	8 3
	Houses—					
	July– September ..	83	1	2	2	2·4
	October–December ..	9	0	0	0	..
Do	Rosh Pinah, Palestine, December.	95	0	0	0	..
Kligler, 1930	Palestine	334†	?	?	5	1·5

* These were hibernating mosquitoes, caught during the winter.
† It seems probable that Kliger's figures include those of Kligler and Liebman.

Experimental Infections—**A. tarsimaculatus.**

Parasite.	Observer.	Locality	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
? ..	Benarroch, 1928 ..	Venezuela	7	0	0	0	..
Q. ..	Davis and Shannon, 1928.	Argentina, S. America.	1	0	0	0	..

Natural Infections—**A. tarsimaculatus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Benarroch, 1928	Venezuela, S. America	71	0	0	0	..

Natural Infections—**A. tessellatus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Schuurman and Schuurman, 1929.	Java, Dutch E. Indies	14	0	..	0	..
Walch and Soesilo, 1929 ..	Sumatra, Dutch E. Indies.	26	0	..	0	..
Soesilo, 1929	Nias, Dutch E. Indies 1926 ..	137	1	..	1	0·7
	1927 ..	60	0	..	0	..
Gater, 1927	Petaling, Malaya ..	148	0	0	0	..
Sweet, 1929-30	Mysore, S. India ..	80	0	0	0	..
Ramsay, 1930	Cachar, Assam, India ..	95	0	0	0	..

Natural Infections—**A. theileri.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
James, 1929	Kampala, Uganda, E. Africa.	33	0	0	0	..

Experimental Infections—**A. umbrosus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Q. ..	Hylkema, 1920 ..	Belawan, Sumatra, Dutch E. Indies.	3	0	0	0	..

Natural Infections—**A. umbrosus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Walch and Soesilo, 1929 ..	Banka, Dutch E. Indies	121	6	..	* 6	5·0

Experimental Infections—**A. vagus.**

Parasite.	Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
? ..	Sur and Sur, 1929	Krishnagar, Bengal, India.	168	..	1	1*	0·6

* Out of 14 specimens dissected in November.

Natural Infections—**A. vagus.**

Observer.	Locality.	Numb. Diss.	Gut Inf.	Gld. Inf.	Tot. Inf.	Percent. Inf.
Borel, 1926	Chaudoc, Cochinchina ..	?	..	..	0	..
Brug and Walch, 1927 ..	Java, Dutch E. Indies	107	0	..	0	..
Gater, 1927 . ..	Malaya	311	0	0	0	..
Maung Gale, 1928 ..	Mawlaik, Burma ..	77	0	0	0	..
Feegrade, 1930b	Pwinbyu, Burma ..	15	0	0	0	..
Strickland, 1929 .. .	Cachar, Assam, India .	1,341	1	0	1	0·07
Ramsay, 1930 . ..	Do. ..	7,601*	0	0	0	..
Ramsay, 1931 †	Jorhat, Assam, India ..	249	0	0	0	..
Sur and Sur, 1929 ..	Krishnagar, Bengal, India.	4,479	0	0	0	..
Do. .	Birnagar, Bengal ..	163	0	0	0	..
Venkataraman, 1929 .	Vizagapatam, Madras, India	50	0	0	0	..
Sweet, 1929-30	Mysore, S. India	903	0	0	0	..

* Ramsay's figures include those of Strickland, above It will be noted, however, that he does not show any of this species as having been found infected. Dr. Ramsay informs me in a private communication that soon after the commencement of his investigations in 1927 he observed what he then believed to be an early gut infection in one specimen, but that subsequent experience convinced him that this was in reality an artefact.

† Private communication.

CORRECTIONS TO INDIAN MEDICAL RESEARCH MEMOIR, No. 7.

Page 23, for 'Hodgson, 1914' read 'Hodgson, 1912.'

Page 35, last line, the quotation is correct, but in the original paper the words 'former' and 'latter' should have been transposed.

Page 41, for 'Senior-White (1925)' read 'Senior-White (1926)'.

Page 49, the reference 'Horne in Hodgson, 1914' refers to Hodgson, E. C., 'A preliminary Note on Malaria in Madras City,' *Ind. Jour. Med. Res.*, I, 4, pp. 702–706.

Page 54, lines 5 to 7, should read 'records that he infected patients with B. T. (1 case out of 22), and M. T. (19 cases out of 43), but failed to infect with Quartan (3 cases).'

Page 75. for 'Gill (1926)' read 'Gill (1916)'.

Page 79, for 'Hodgson, 1914' read 'Hodgson, 1912.'

Page 99, reference No. 70, for '1920' read '1921.'

Page 109, reference No. 277, for 'pp. 975–985' read 'pp. 575–585.'

Page 111 reference No. 318, for 'VII' read 'VIII.'

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REPORT ON THE CONTROL OF MALARIA DURING THE SARDA CANAL CONSTRUCTION (1920–1929).

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[October 23rd, 1930.]

CONTENTS.

I. INTRODUCTION.

(1) *History of Sarda canal project.*

THE first scheme for a series of canals from the Sarda river was prepared in 1870 with a view to irrigating the Province of Oudh* and thus relieving or

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* *Note.*—The United Provinces embrace the following districts :—

Province of Agra.—Dehra Dun, Saharanpur, Muzaffarnagar, Meerut, Bulandshahr, Aligarh, Muttra, Agra, Mainpur, Etah, Bareilly, Bijnor, Budaun, Moradabad, Shahjahanpur, Pilibhit, Farrukhabad, Etawah, Cawnpore, Fatehpur, Allahabad, Jhansi, Jalaun, Hamirpur, Banda, Benares, Mirzapur, Jaunpur, Ghazipur, Ballia, Gorakhpur, Basti, Azamgarh, Naini Tal, Almora and Garhwal.

Province of Oudh.—Lucknow, Unao, Rao Bareli, Sitapur, Hardoi, Kheri, Fyzabad, Gonda, Bahraich, Sultanpur, Partabgarh and Bara Banki.

abolishing the constantly recurring famines. This and six subsequent schemes were rejected in the last century. on account of the opposition of the Taluqdars of Oudh, through whose lands the canals were to pass. The reasons for this opposition appear chiefly to have been due to the fact that in famine years the landowners could always prevail upon Government to remit the land revenue wholly or partly, in proportion to the failure of the monsoon, and to the arguments that canal irrigation would prove more costly than lift irrigation from ponds, tanks, wells and marshes.

One of the schemes provided for a Sarda-Ganges 'feeder' canal to carry Sarda river water across the *Terai* through the Indian State of Rampur and the districts of Moradabad and Budaun to the Ganges river at Narora in the Aligarh district. In addition to irrigating the districts through which it would pass it was also designed to provide water for the districts of Shahjahanpur and Bareilly. This scheme appears to have been dropped because the ever-increasing cost of lift irrigation and the severe famines of 1897-98 and of 1907-08 at last compelled the Taluqdars of Oudh to request Government to reconsider the scheme for providing canal irrigation in Oudh.

In 1913 a new scheme was evolved combining the Sarda Oudh canal scheme with that part of the Sarda-Ganges feeder scheme (the Sarda-Kichha feeder scheme), which would irrigate the districts of Bareilly, Shahjahanpur and Pilibhit in addition to the districts of Oudh.* This scheme, though prepared and submitted before the Great War, was not sanctioned till 1919, the delay being partly due to the necessity of proving to the Government of India that sufficient drainage cuts were incorporated in the scheme to prevent water-logging. This provision was necessary as there are many tracts, through which the distributing channels must pass, where the subsoil water-level is already very high and malaria prevalent. This condition is favoured by a heavy, though erratic, monsoon rainfall of about 40 inches, which collects in swamps and depressions, forming breeding grounds for mosquitoes. Drains were also to be provided where there was a good slope in the country, if at the same time many *jhils* existed or the subsoil water-level was high. Tracts already water-logged and tracts where water-logging might occur, were canal irrigation introduced, were excluded from the scheme. Hence, in this scheme, a rise in the malarial incidence similar to that which followed the opening of the Ganges canal in 1854 was guarded against, by providing drainage cuts and prohibiting irrigation or the provision of channels in all areas where the subsoil water-level was already high and where there would be a danger of water-logging and consequent increase in the incidence of malaria.

* *Note.*—The United Provinces embrace the following districts :—

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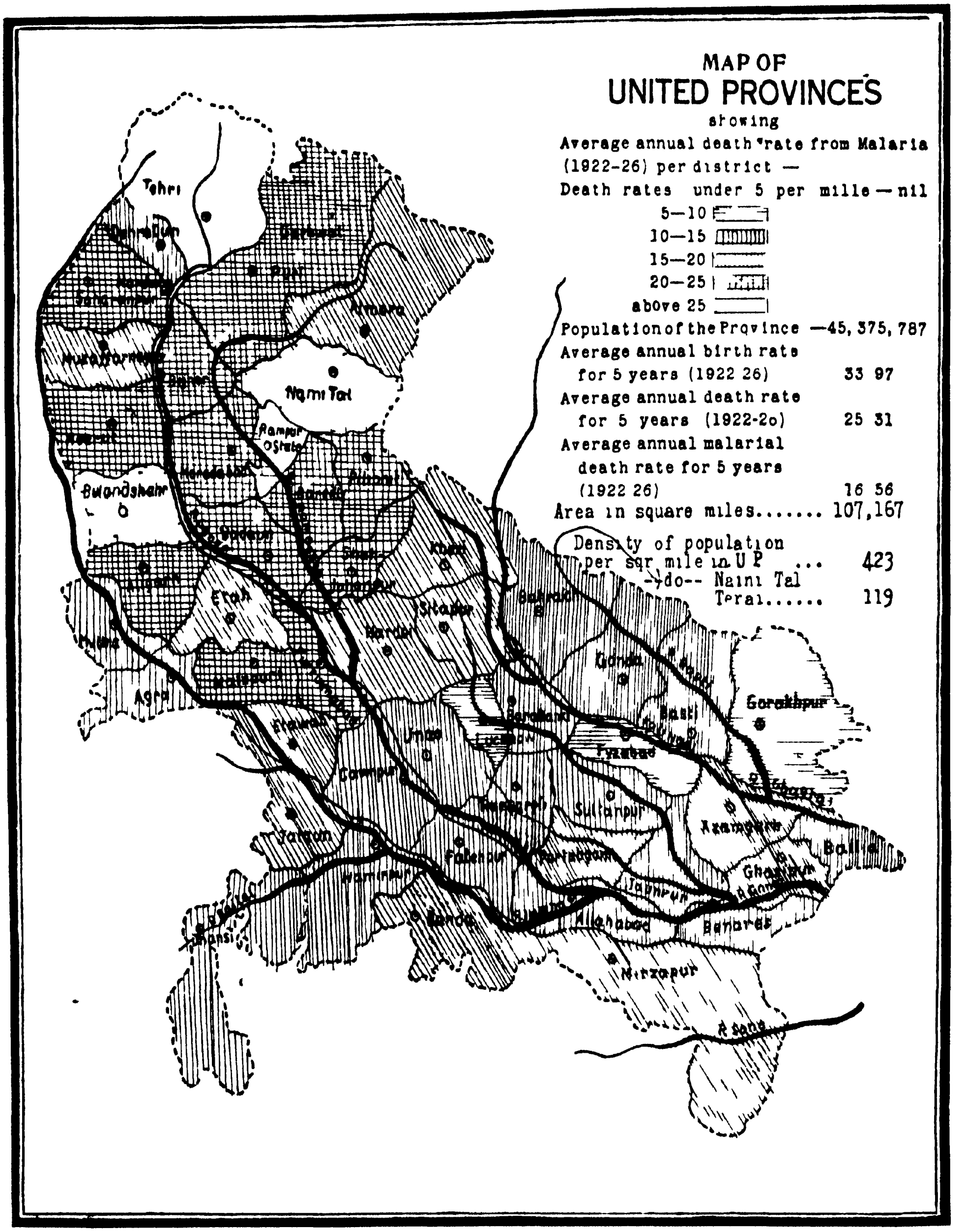
Province of Oudh.—Lucknow, Unao, Rae Bareli, Sitapur, Hardoi, Kheri, Fyzabad, Gonda, Bahraich, Sultanpur, Partabgarh and Bara Banki.

MAP.


MAP OF
UNITED PROVINCES
showing
Average annual death rate from Malaria (1922-26) per district —
Death rates under 5 per mille — nil
5—10
10—15
15—20
20—25
above 25
Population of the Province —45, 375, 787
Average annual birth rate for 5 years (1922 26) 33 97
Average annual death rate for 5 years (1922-26) 25 31
Average annual malarial death rate for 5 years (1922 26) 16 56
Area in square miles....... 107,167
Density of population per sqr mile in U P ... 423
-do-- Naini Tal Terai...... 119
Tehri
Naini Tal
Bulandshahr
Gorakhpur
Agra
Cawnpur
Allahabad
Benares
Mirzapur
Jhansi
R Sone

(2) *Extent of the scheme.*

Some idea of the magnitude of the canal and the works involved can be formed from the following data :—

(1) The canal system is 4,000 miles long and is thus the longest in the world.

(2) In addition to this, 1,800 miles of drainage channels have been laid down.

(3) The area commanded is approximately seven million acres, i.e., a country as large as the whole cultivable area of Egypt.

(4) The total cost is Rs. 95 millions.

(5) The canal at the headworks is 350 feet wide.

(6) The labour required on construction yearly was on an average 10,000 to 15,000 men in each of the thirteen divisions into which the whole works were divided.

(3) *Relative healthiness of districts in the canal zone.*

The tract of country in which canal operations had to be carried out is roughly divisible into three distinct zones from the malaria standpoint :—

(1) The relatively healthy zone in the plains of Oudh—spleen rate variable, but not over 10 per cent.

(2) The less healthy zone in the plains of Rohilkhand—spleen rate 10 to 50 per cent.

(3) The unhealthiest zone in the notoriously malarious 'Terai' of the United Provinces. The headworks and the upper reaches of the main branches are in this region and large concentrations of labour were involved. The spleen rate averaged 75 per cent.

The districts in these zones give the following statistics over a five years period 1924–1928 :—

Districts.	Crude death rate.	Crude fever death rate.
Zone (1)—		
Bara Banki	22·44	16·24
Lucknow	21·75	15·88
Unao	20·77	12·66
Hardoi	22·51	18·06
Sitapur	22·74	18·09
Zone (2)—		
Shahjahanpur plains	30·97	23·05
Bareilly plains	30·80	23·60
Zone (3)—		
Naini Tal Terai	48·00	42·00
Kheri Terai	52·00	40·00
Shahjahanpur Terai	39·00	31·00
Bareilly Terai	36·00	29·00

The average figures per revenue district for 1922–26 are given in the Map (*facing* p. 51).

It is to be remembered that these figures are based on the reports of the village headman, whose ideas as to what constitutes malaria, although more defined than

his ideas on other diseases, are extremely vague. This official has innumerable other duties to perform and often does not record deaths till months after they have occurred—if then.

This report deals mainly with the work carried out in part of the third zone, at the headworks of the canal.

II. General features of the headworks area of the Terai.

(1) *Geographical features.*

The headworks of the canal are situated on the Sarda river, 1½ miles east from the railway station of Banbassa on the R. and K. Railway (81·8′ East and 28·5′ North). The area is densely covered with jungle and intersected by ravines. The jungle consists mainly of Sal (*Shoria robusta*), Khair (*Acacia catechu*) and Shisham (*Dalbergia sissu*) and the forest is impenetrable after the rains except on elephants. The Sarda river itself is about 1 mile broad at the canal inlet, and while swollen and rapid during the rains—the flood flow recorded in 1924 was 600,000 c. ft. per second—decreases in size rapidly from October onwards, although sudden floods, due to hill storms and snow melting in Nepal, frequently occur. In the dry weather the river dwindles considerably and then consists of several channels running in a sandy and rocky bed. It was impossible to tell until the rains were over whether the main channel would be left on the Nepal or British side of the river, what breeding places, wash-outs and seepage areas would remain. or the extent of the damage to the earth works erected to block off old channels in the labour camp areas.

The jungle is also intersected near the headworks by numerous other hill streams, the principal ones being the Jagbura, the Sonia, the Gorkha and the Kakra. These hill streams in their upper regions are small and winding, and are overgrown with weeds, but near the canal area have broad and uneven stony beds which are completely covered when the streams are swollen during the rains. After the rains, however, there is a rapid fall in volume, the current becoming confined to narrow channels; broad, marshy, weed-grown tracts and numerous pools are left which persist throughout the year. Some of the smaller streams, on the other hand, have narrow winding beds with high irregular banks densely covered with jungle grass. In the dry season these present the appearance of pools or semi-stagnant ditches overgrown with tall grass, reeds and scrub. Seepage outcrops exist throughout the whole headworks area; the marshy lands, covered with reeds and elephant grass, surround the slightly higher cliffs on which the labourers and staff were encamped. The mosquito-breeding places were mostly in slowly flowing water among elephant grass and in seepage areas exposed to light; few were found in shaded waters in the jungle around the camps. These various breeding grounds in the immediate vicinity of the headworks camp at Banbassa exist even now after 9 years' work and each year the floods form new channels and marshes and the fresh breeding places have to be laboriously sought out after cutting down the impenetrable jungle grass.

PHOTOGRAPH 1.

Typical of the United Provinces Terai: an opening in the jungle infested with *A. listonii*, *A. culicifacies* and *A. maculipalpis* both before and after clearance.

(2) *Nature of aboriginal inhabitants.*

The population of the Banbassa villages is, for the most part, migratory, consisting chiefly of hill men who come down for the winter months to obtain better pasture for their cattle. They employ their leisure time in trade and in the cultivation of spring crops, which a naturally fertile and almost virgin soil produces with the maximum of profit and the minimum of labour. As the unhealthy reputation and high death rate of the tract from time immemorial has resulted in labour being hard to get and very expensive, many of these hill men find lucrative employment as wood-cutters, sawyers and coolies.

The aboriginal tribes of the Terai tract, the Tharus and, to a lesser extent, the Bhuksas, form the residual population. The size of the population is stationary and numbers about 16,000 and has long been known to have a relative tolerance to malaria as long as they remain in the malaria zone. The death rate among Tharu children under one year of age is some 50 per cent higher than that in children of the plains cultivator who settles in the tract, but after 1 year the death rate among Tharus decreases greatly compared to the residents of other castes. The spleen rates among Tharu adults is some 10 per cent less than among Tharu children but the soft spleen of an acute attack is relatively seldom met with in adults, the adult spleen being hard, usually three to four fingerbreaths below the costal margin and definitely decreasing in size with age. The Tharus are cultivators of a high order and are a comparatively wealthy race. Their villages are very clean, the mosquito density is low, thus contrasting with the jungle beyond the highly cultivated circle surrounding the villages, where the mosquito density is heavy. Very few (if any) of the plains cultivators will come into the Tharu tract to settle down because according to them 'it means certain death.' The Bhuksas are seldom found in the Banbassa Terai but occupy certain villages in the Haldwani Terai. They also are aborigines, but are a poor race of cultivators and fishermen and make no attempt, as do the Tharus, to cultivate up to the extent of their available water-supply. The Bhuksas employ Desi* servants among whom the spleen rate is 100 per cent, while the Bhuksa spleen rate in children averages 80 per cent and in adults 70 per cent.

The hill people, who visit the Terai of Banbassa yearly, occupy 'Gots' or cattle stations where they annually construct grass huts. Most of them cultivate a little land because agriculturists in this area are allowed free grazing for a certain number of cattle per plough, but the cultivated area per family is not large. The breeding of cattle and the manufacture and sale of ghee (clarified butter) constitute their chief occupations.

(3) *Geology.*

The Terai tract consists of a zone recently formed by the Gangetic alluvium. The soil is mainly clayey and retentive of moisture, the top layer being covered with

* Desis mean emigrants from the plains.

loam very rich in vegetable manure. The Terai lies between 28° 43′ and 29° 26′ North latitude and between 78° 53′ and 80° East longitude with an average width of eleven miles from north to south. Immediately to the north of the Terai and between it and the sub-Himalayan range lies a belt of stony, waterless country known as the Bhabar, which is also covered with vast stretches of thick jungle.

(4) *Climate.*

The climate of the Terai differs from that of the adjoining plains of Rohilkhand chiefly in humidity and in the diurnal variations of temperature, due to the nature of the soil and the dense forest. The heavy incidence of pneumonia and malaria among the inhabitants of the tracts during the various seasons has, for centuries, been attributed to the combined effect of the climate, the jungle, the high water level and the excessive moisture with the great heat.

'From about the end of April the climate begins to be dangerous while in the rains it is positively deadly. In the hot weather and the rains there has been a history of a peculiarly malignant type of malarial fever amongst the immigrants' (*U. P. Gazeteer*). Mr. C. H. Roberts in the Assessment Report of 1890 writes 'The climate is at all times of the year trying owing to the proximity of the hills, the circulation of the air being much retarded. The direct and refracted sun heat makes it close, hot and muggy. In the months of August, September and October when forest undergrowth grows up, the climate is extremely malarious. During most of the year particularly in the cold weather a nasty cold wind sets in after sundown which is trying to the constitution after the heat of the day.' The temperature rarely exceeds 105°F. in the hottest months of the year while the average day temperature in winter is about 50°F. The diurnal variation is as great as 30°F. in the summer and 25°F. in the winter. The humidity remains between 60 per cent and 90 per cent in the months of March, April, July, August, September and October.

The variation in the climate is very largely due to the difference in the nature of the rainfall. The average rainfall is much greater than in the plains and there is hardly a rainless month. The rainy season begins earlier than in the plains (June) and lasts up to the end of September or the middle of October. There is almost always a considérable winter rainfall which is heaviest in the months of December and January, but is seldom of long duration. The average rainfall is 91·6 inches per annum, the wettest months being June to September, while January, April, November and December are the driest months.

Graph IV (p. 108) is only given as approximate as far as the temperature and humidity figures go, owing to certain omissions in the recording due to the absence of the malaria officers on tour. It has, however, been corrected from data available from neighbouring areas in the Terai.

Rainfall statement for the years 1921 *to* 1929.

Months.	Rainfall in inches.									Monthly average. Inches.
	1921.	1922.	1923.	1924.	1925.	1926.	1927.	1928.	1929.	
January ..	5·1	Nil	0·6	Nil	0·05	1·65	Nil	3·76	2·28	1·49
February ..	3·0	Nil	3·7	1·5	Nil	0·66	1·31	10·52	0·03	2·41
March ..	3·2	Nil	Nil	0·6	0·07	7 5	4·15	0·03	0·84	1·82
April ..	3·8	Nil	Nil	0·05	1·05	0·5	0·15	1·32	0·22	0·79
May ..	3·3	Nil	Nil	0·07	0·78	0·07	1·37	2·7	1·12	1·5
June ..	1·3	11·4	4·55	3·33	16·08	1·10	20·10	8·82	6 35	6·11
July ..	15·9	61·7	33·1	26·4	16·72	25·60	17·05	27·53	Works closed.	28·0
August ..	41·3	45·0	32·3	27 7	39·76	22·28	27·7	11·94		31·0
September ..	14·6	29·8	30·1	12·3	2·25	5·70	10·65	4·40		13·72
October ..	1·4	Nil	4·3	4·2	0·60	Nil	3·05	0·15		1·71
November ..	Nil	Nil	Nil	Nil	0·25	0·05	5·15	0·3		0·72
December ..	Nil	2·1	Nil	0·31	Nil	Nil	0·1	0·52*		0·38
Total ..	92·9	150·00	108·65	76·46	77·07	64·20	91·78	71·99	10·84	

Average annual rainfall—91·6 inches.

III. The malaria problem in the Banbassa Terai.

As an example of the malarial problem in the headworks area, the malarial incidence in this and similar areas of the Terai is cent per cent. Special concessions in the shape of grants to cultivators and the complete remission of revenue have for years been given by Government to cultivators who will settle temporarily in these tracts. The Banbassa Terai attracts no plains cultivators but only, in the cold weather, hill men who come down to graze their cattle. Other Terai areas attract a certain number of plains cultivators, refugees, etc., from surrounding districts, etc. Of these areas the Kashipur Terai may be quoted. The 'vital index' * of the people inhabiting the Kashipur tracts of the Terai, which have been cultivated for years and in which, therefore, the jungle conditions have been greatly ameliorated, works out over a period of 50 years at 80 per cent. Were it not for

* The vital index, as expressed by the formula $\frac{\text{deaths} \times 100}{\text{births}}$, falls markedly during *epidemics* of malaria in hyperendemic tracts and rises to the stationary 100 line in exactly five years. The additional lowering by occasional epidemics is of little importance when considering the effect of hyperendemic malaria over a period of years.

the fact that fresh immigration is continually going on and people are being attracted by the concessions, depopulation would automatically occur.

The 50 years average statistics for the tract as recorded by the village headmen work out at: death rate 45·3 per mille; infantile mortality rate approximately 280 per mille; birth rate 35·9 per mille of population and the ratio of 'fever deaths' to total deaths 90·5 per cent. In 43 per cent of the villages the inhabitants have been found on survey to have spleen rates of over 75 per cent, and in another 20 per cent of the villages, spleen rates of over 50 per cent.

The vital statistics of the small town of Tanakpur, 6 miles from Banbassa, would give a good indication of the incidence of malaria. This town is, however, merely the trading centre at the railway terminus and has a very large nomadic population in the cold weather, while the population during the rains only consists of those people who are compelled to live in Tanakpur. Amongst these the malarial incidence is 100 per cent as judged by spleen rates.

Annual epidemics of malaria would certainly have occurred at the headworks camps because

(1) The subsoil water-level is very high after the rains when all the ground is sodden and marshy. The 'cliffs' where the camps were situated, are in close proximity to, or intersected by, lower ground, ravines, etc., wherein seepage outcrops, pools and swamps existed. On this account active breeding places occurred almost everywhere.

(2) Jungle conditions existed over the area.

(3) The temperature and humidity were such that mosquito breeding occurred throughout the whole year and became very active between the 1st of March and the end of June and between the beginning of September and the 31st of October.

(4) The bulk of the labour introduced was from a tract in the province where the incidence of malaria among adults is relatively small, and therefore non-immunes were imported in large numbers into an intensely malarious zone.

(5) A large proportion of the children brought in by local labourers—and the labourers themselves who returned in succeeding years to the works—formed an annual 'reservoir' of malarial infection, while a small reservoir of infection existed in the men kept on the works during the rains, who all, without exception, contracted malaria.

(6) The anopheline mosquitoes which abound are known to be most dangerous carriers of malaria.

(7) Domestic cattle which might form a buffer to protect the imported population, at least partially, were practically non-existant in the headworks area.

(8) Food prices were comparatively high.

Thus the conditions existing were such that epidemic malaria was certain to occur in aggregations of labour every autumn and, as in such epidemics 90 per cent of the population is always infected, the incubation period extremely short and

the mortality high. It is, therefore, obvious that the headworks could not have been built without complete and extensive anti-malarial measures.

An epidemic due to such causes did indeed occur in one of the earliest years of the work. 'In the first year of the works, before anti-malarial measures were started, work had to be closed down in April because 96 men out of every 100 imported were down with fever at one time. Contractors refused to carry on the work and one after the other cleared out, and it was realized that unless active measures were taken the headworks would never be completed' (Sir B. Darley, *Kt.*, Chief Engineer, Sarda Construction).

IV. Original proposals and arrangements.

(*A*) As the result of correspondence between the Government of India and the Government of the United Provinces, the Director of Public Health, United Provinces, put up certain proposals towards the end of 1919 'for the provision of medical and sanitary arrangements during the canal operations.' The chief points in these proposals were for the provision of a temporary hospital to provide for indoor accommodation to the extent of 5 per cent of the total labour population of the headworks, arrangements for the prevention of the spread of malaria and infectious diseases and the deputation of a Deputy Sanitary Commissioner on special duty to supervise the medical, anti-malaria and sanitary work.

A committee which met on December 11, 1919, to discuss the arrangements necessary for safeguarding the health of the staff to be employed on the construction of the Sarda canal made the following recommendations :—

'(1) To depute Dr. A. N. Mukerji, L.M.S., late Assistant Malaria Officer, to undertake a preliminary survey in the month of March 1920, and to report what staff would be required for anti-malarial work.

'(2) That all breeding grounds adjacent to the area of the headworks and the main branches of the canal passing through the Bhabar and Terai areas should be eradicated.

'(3) That no work should be carried out in these areas between May 15 and November 15.

'(4) That samples of blood of imported labourers should be examined and that those labourers found to be carriers of the sexual forms of parasites be rejected.

'(5) That the entrance of children to the area of works should be restricted to a minimum.

'(6) That quinine prophylaxis should be continued during periods considered necessary by the sanitary authorities.

'(7) That mosquito-proof houses be provided for the superior personnel.

'(8) That travelling dispensaries be provided in sufficient number to attend the sick.

'(9) That suitable stationary hospitals be erected at chief aggregations of labour.

'(10) That a Deputy Sanitary Commissioner be deputed to be in charge of the medical and sanitary arrangements.

'(11) That, wherever possible, water-supply in the shape of tube wells be provided for the labour and, where not possible, only such water be used for drinking purposes as is directed by the sanitary authorities.'

In view of what follows in this report, items 3, 4, 5 and 7 are noteworthy.

(*B*) Dr. A. N. Mukerji undertook a preliminary survey in March and April 1920, and submitted a report in which he made the following recommendations :—

'(1) That prophylactic quinine be issued.

'(2) That small larvæ-eating fish be introduced into streams.

'(3) That mosquito curtains be provided to all the staff working on the canals.

'(4) That wire-gauze doors and windows with automatic closing arrangements be provided in all residential quarters.

'(5) That mosquito traps be issued to labourers.

'(6) That *Neem* and Eucalyptus trees be planted in the camps.

'(7) That all "pukka" quarters be fumigated regularly.

'(8) That the "kachcha" anti-malaria drainage channels made, be cunetted.'

An issue of mosquito curtains to the subordinate Government staff was made, but the Malariologist appears not to have been in favour of expending the large sums necessary to mosquito-proof the houses, more especially those of subordinates and coolies.

This report by Dr. Mukerji was forwarded to Government by the Director of Public Health, United Provinces, who emphasized the necessity for carrying out the recommendations of Dr. Mukerji in full and pointed out that, if no systematic action was taken in the matter, very serious consequences might result.

(*C*) In the cold weather of 1919-20 no anti-malaria measures were taken, because it was not known where the headworks would be situated or the camps built. By March 1920, the preliminary surveys were completed and the work of felling the forest and preparing the lay-out and designs commenced. The anti-malaria work proper therefore commenced in 1920-21. There are unfortunately no reliable statistics of the state of the health of those engaged on this work at that time. The preliminary work of the engineers consisted of making earth 'bunds' (embankments) to block off the various channels of the Sarda which cut across the line of the future canal. It was at this time (15th—25th April, 1920) that the incidence of malaria rose to such an extent that the complete labour corps was ill and the contractors refused to continue work. The first anti-malaria measures necessary consisted, as they have consisted in October every year since, in cutting down the jungle grass to expose actual and potential breeding places and then to carry out a rapid malaria survey, during which investigation all collections of water, seepage areas, reed-covered swamps, etc., were oiled in a wholesale manner once weekly.

In October in any year there was no question of looking for and oiling only those waters actually containing larvæ.

PHOTOGRAPH 2

Borrow-pits on the edge of the Sarda river.

Every collection of water, excluding the main channel of the river, and even every area of damp ground containing hoof or foot marks, formed an actual breeding place of one or other of the various carrier anophelines found. This is typical of this 'Terai.'

The coolies, who made up the jungle-cutting and anti-malaria gangs, frequently refused to carry out the work owing to the difficulties of penetrating the reed-grown swamps and elephant grass areas, which were infested with leeches and snakes.

V. Preliminary surveys and work.

(*A*) *Breeding places of mosquitoes.*

The following types of breeding places were incriminated in the preliminary survey :—

(1) The whole area of the old bed of the river immediately below the cliff on which the camp was to be located. This was a jungle-covered valley between the cliff and the actual river and was intersected by sluggish streams and swamps which cut off the 'islands' between the cliff and the main channel of the Sarda.

(2) Some two hundred yards below the above—

(*a*) A large lake of stagnant water, about 400 yards long and 50 yards wide, with grass-grown edges;

(*b*) The water in the various slow running and stagnant channels of the river.

(3) Small sluggish streams running through the jungle in the close vicinity of the cliff. These streams were used for irrigation purposes by the villages of Banbassa.

(4) Rice fields and irrigation channels near the railway station and the villages.

(5) A large pond some 100 yards long and 30 yards wide covered with green vegetation, about 200 yards from the Banbassa railway station.

(6) Stagnant water under the culvert at the bend of the Khatima road on both sides. Stagnant water in open sunlit spaces in deep jungle.

(7) Borrow-pits—Numerous borrow-pits along the railway line that extends from Banbassa to Pilibhit and others on the 'kachcha' road leading to Khatima.

(8) Hill streams crossing the line of the canal and in close vicinity to the projected site of the labour camps.

Besides these, the edges of the following principal hill streams—the Hoodi nala, the Jagbura, the Sunya nala, the Gurka and the Kakra with their tributaries and backwaters. These, as will be seen, were very important breeding grounds and also most difficult to tackle.

(9) Numerous small seepage outcrops all over the area.

As soon as the chief actual and potential breeding grounds of the anophelines were incriminated, a camp laboratory was opened at the site for the systematic specific classification of the various mosquitoes caught, for breeding out larvæ and for making routine blood examinations of all fever cases.

(B) *Anophelines.*

The following species of adult anophelines were caught and identified in the first malarial survey of 1920 :—

(1) *A. willmori* (forming about 90 per cent of the daily catch), (2) *A. listonii*, (3) *A. barbirostris*, (4) *A. fuliginosus* var. *adiei*, (5) *A. fuliginosus* (type form), (6) *A. culicifacies*, (7) *A. maculipalpis*, (8) *A. stephensi*, (9) *A. jamesi* and (10) *A. turkhudi*.

It is interesting to note that only three specimens of *A. jamesi* and *A. turkhudi* have been caught up till now in Banbassa, although they have been found at Tanapur, five miles up the river, on numerous occasions.

The first seven anophelines were also bred out from larvæ collected from the various breeding grounds in this survey.

(C) *Statistics.*

From the only vital statistics available for 1920, it appears that the average daily population in November and December worked out at 360 and 1,500 respectively, while the malarial incidence was 50 per cent in November and 20 per cent in December. The spleen rate amongst 14 Tharu children recruited locally worked out at 70 per cent. Of the blood examinations of fever cases among imported labourers made in these months, 25 per cent showed benign tertian parasites and only 1 per cent subtertian parasites : these findings are remarkable for November and December. The thin film method of examination was used.

(D) *Medical arrangements.*

Subsequently a canal hospital under a Sub-Assistant Surgeon was opened to treat all cases of fever and minor ailments amongst the labour. It was realized from the beginning that, especially under Indian conditions when the work is done by the contractors over whose labour a medical staff could exercise no control whatsoever, the active co-operation of the engineers was essential if any result whatsoever was to be obtained.

The early history of this time bears evidence that the medical staff were working under great difficulties and indeed these difficulties existed even up to the completion of the work. The constant refusal of contractors to take effective steps to have their labourers at quinine parades, unless pressure was brought to bear by the Executive Engineer, who had really no power over contractors and no time to attend parades, threw enormous work on the medical staff. These difficulties are common to all anti-malaria works the world over and are especially difficult in dealing with uncontrolled coolies working under contractors in India. Mass treatment by quinine meant that medical officers had to go round the works in the daytime and wait at the entrances of the camp in the evenings, offering quinine to those who were pleased to take it. Coolies often refused to take quinine and when pressure was brought to bear, it was found that they would stay out in the works until dusk or even dark and enter the camp when the medical officers had gone away, fearing the risk of wild animals less than the supposed ill effects of quinine.

The utter impossibility of carrying out any reliable work in these conditions is obvious.

(*E*) *Anti-malaria measures.*

The following are briefly the anti-malaria works carried out in the headworks area in the first few years of the work :—

(1) Jungle cutting, especially in the ravines, marshes and streams and around the camps. The elephant grass when dry was collected and burnt.

(2) Attempted mass treatment by distributing 10 grains of quinine, on two consecutive days per week, to all employees who could be persuaded to take it.

(3) Supplying mosquito traps to officers and removing the mosquitoes every morning for classification and destruction. Attempts appear to have been made to do this also in the huts used by the labour, but it was far from satisfactory.

(4) The employment of small anti-malaria gangs in filling up or otherwise treating pools, stagnant ditches, seepages areas, residual flood water collections and in making temporary drains, etc.

VI. Camp sites and housing.

The elementary principle that in a malarious tract labour must be concentrated into large camps, or, preferably, in a country subject to epidemics of cholera, in smaller camps, but all within a definite circumscribed area, was duly pointed out and as far as could reasonably be demanded, was adhered to. An even more important point that the camp should not be near the main breeding areas deserves consideration. At first the camp consisted, and could scarcely consist otherwise than, of grass huts in clearings near the various earthworks which were being erected all over the area. Later when the work became more concentrated the main camp was located above the cliff at the bend of the future canal. Still later in 1923 when the barrage had to be constructed in the river, the main body of labour was concentrated on an island on the right bank of the Sarda. This island was bounded on the south and west by an open river channel, which was not breeding anophelines to any extent. Later, however, when this channel was cut off by earthworks, this channel, and a bed of boulders to the west of this main camp, became marsh land and formed a serious breeding place. This could not have been foreseen, nor could the camp have been situated elsewhere, as the contractors demanded camps near their works. It was also impossible to transport several thousand men morning and evening to the works situated between 2 and 3 miles away from the only other practicable site.

The dwellings of the labourers consisted of grass 'chappars' (huts), strengthened with bamboo and roofed with grass. These had to be built by the coolies themselves on arrival in camp and, as unlimited grass, fire-wood, etc., was available, the coolies were able to provide themselves with better accommodation and had more comfort than is usual in construction camps. As is the custom of these people, they slept on the floor in whatever clothes and blankets they possessed.

By 1922 stone houses with thatched roofs were ready for the superior officers, overseers, and as a hospital. Electric light was put into these buildings at the end of 1926, and electric fans provided for officers in the hot weather of 1927. The houses were not screened.

VII. Hospital accommodation.

In the earlier years, when the work consisted of cutting the virgin forest and making surveys to determine the site of the headworks, tents were used as a small detention hospital. It would appear that coolies would come to the medical officer complaining of fever, have blood slides taken, receive a bottle of quinine mixture and disappear to their respective camps. As proper control and supervision was impossible in these circumstances, it is obvious that these cases became in time active foci for the infection of mosquitoes.

Early in 1922 a twenty-bedded hospital and medical officer's quarters were ready, while five grass huts were erected in a clearing behind the hospital, to serve as an infectious diseases hospital.

The situation of the hospital was about half a mile from the railway station and near the workshops. As the light railway line passed the hospital, trollies were available for the conveyance of sick from the works.

A Sub-Assistant Surgeon was in charge of the hospital, but in 1923 the staff was increased to two medical officers, two compounders, a dresser, four ward orderlies, two cooks and two sweepers.

In addition to this hospital and its staff. travelling dispensaries, of which six were placed at the disposal of the Assistant Director of Public Health for use on the canal, were moved into the headworks area as required by the demands of the season or of the increasing population. When the main hospital was constructed the chief concentration of labour was in close proximity to it, but by 1923 the main camp was situated at the river bank about a mile from the hospital. It was then found that many coolies were not reporting sick, chiefly because of the fact that they had no time or inclination to walk the necessary distance either at the beginning or at the end of the day's work. Accordingly a dispensary was built in the centre of the camp and a medical officer visited this dispensary during the morning and evening hours. It was found that coolies really requiring admission to the hospital refused to go into the main hospital and thus be separated from their families. For this reason a detention hospital consisting of a male and a female ward, capable of accommodating 10 beds, was built in this camp in 1926. Although this hospital was only made of grass and bamboo it filled a distinct want, especially for those labourers who were injured or taken sick while working on the weir, barrage and bridge. In the working season, beginning with October 1926, a travelling dispensary was moved into this camp, so that a resident medical officer would be available at any time during the day or night.

A travelling dispensary was also on duty during the whole of the construction work at the Jagbura camp, three miles east of the main camp, where the labour

PHOTOGRAPH 3.

Oiling No. 5 marsh.

No. 5 marsh in December after 3 months' draining. *A. listonii* in seepage outcrops; *A. maculipalpis* in hoof marks: *A. culicifacies* after showers.

concentration averaged from 1,000 to 4,000. Another travelling dispensary was stationed at the Khatima camp, about 6 miles from the main camp, where, until 1927, from 1,000 to 3,000 labourers were employed.

As the barrage was extended across the river in the beginning of 1927, labourers began to erect their huts on the sand in the islands in the centre of the river and on the Nepal bank of the river, which was about a mile away from the main camp. As these huts increased rapidly in number, it was found necessary to post another medical officer with a travelling dispensary to this camp specially to supervise the sanitary and anti-malaria measures and make daily visits to the huts to detect sick cases.

These travelling dispensaries were maintained by the Public Health Department and loaned to the canal, so that any estimate of the cost of providing the medical staff for the canal must also include these public health units. These dispensaries are essentially mobile. They consist of tents for a medical officer and his attendant and panniers of drugs, disinfectants and instruments, and are moved as the main concentration of labour moves from camp to camp.

VIII. Organization.

The medical and sanitary arrangements of the headworks and the whole of the Sarda canal zone were under the direct control and supervision of the Malariologist for the time being to the Government of the United Provinces, who was also Chief Medical Officer of the Sarda canal area. The Malariologist was assisted by two Assistant Malaria Officers and four 'mosquito catchers' were provided. This staff constituted the permanent malaria branch of the Public Health Department, United Provinces, and the work on the canal was carried out in addition to the general anti-malaria work of the Province.

The malaria problem in the rest of the Sarda canal zone was more or less simple. All that was necessary being to visit the areas periodically, to advise on the various measures necessary, to examine the sickness returns and inspect the local dispensaries.

The malaria officers resided in the headworks camps from 1922 to April of 1927. Owing to pressure of work in other malarious areas in the Terai, they, however, had to leave the headworks in April 1927, and it was thought that as the use of paris green and fumigation was now a routine it could be left to organized gangs working under a local medical officer. On visiting the area some 18 days later it was obvious that the anti-malaria measures could not be left entirely to the supervision and direction, even of the local medical officers. The practice from then until the completion of the construction of the canal, was for the malaria officers to visit the works for a few days once weekly or at longer intervals as the season demanded. The spreading of paris green and the fumigation work was done during their residence, and they themselves investigated the sickness incidence by visiting huts in the camps, and the sick parades.

The strength of the local hospital staff has been already given. The anti-malaria gang consisted normally of 25 men working directly under two mates. The

malariologist, however, had power to employ as many men as necessary, and at the beginning of each session from 1921 to 1925 approximately 100 men were employed on the initial jungle clearance, oiling, etc., necessary to prepare the area for the arrival of the main body of labour.

From 1926 this initial jungle clearance was done by contract. This ultimately proved a much cheaper proposition and expedited the work, because once paris green had been used broadcast over all the breeding areas of the year before—now of course again obscured by elephant grass and undergrowth—the anti-malaria gang only required to follow up the labourers to clean and repair the old drains and remove weeds from water-ways. Simultaneously with this work the fumigation of rest-houses, quarters, etc., was carried out and attempts were made to detect the malaria carriers who had been on the works during the rains.

When the immediate area to be occupied by the camps had been examined and taken in hand the outlying breeding places were investigated, as those known to have been responsible for localized outbreaks of malaria in the main camp were scattered over an area approximately 4 miles square. This examination involved the collection and rearing out of larvæ for identification purposes daily and the collection of adults catches from the huts in the various camps.

IX. Factors obviating any benefit from previous anti-malaria work.

It will thus be seen that in the beginning of each session, no matter what anti-malaria work had been done in the year before, or in previous years, the extent of the anti-larval problem was unknown, especially as, with the exception of a few feet of permanent anti-malaria drains, no permanent drains existed until 1927. The 'kachcha' drains had to be re-dug each October, as the heavy rains had invariably filled them up with silt and boulders and their edges had become broken down.

One of the main problems, when oil was being used as a larvicide, was to stop the profuse breeding which went on in seepage outcrops and in footprints, etc., in water-logged and sodden ground. As these sodden areas at the end of the rains were extensive, even existing in high ground above the cliff, the time at the disposal of the staff between the beginning of October and the advent of those labourers who began drifting into camp from the middle of October, was extremely short. It is only proposed in a general way to mention these breeding grounds, as it will serve no useful purpose to enumerate the actual permanent or temporary breeding places found every year after the floods. The permanent breeding places consisted, as before mentioned, of various hill streams, swamps, seepage outcrops, the edge of the river, certain borrow-pits, brick kiln excavations, and small channels used for irrigating rice fields by the Tharu villages. These were divided into major or minor anopheline propagation areas according to their larval intensity.

X. The labour problem.

(1) While along the course of the canal efficient and cheap labour was obtainable in abundance locally, in the headworks area the aboriginal Tharu tribe only was available and this tribe will not seek employment. It was also impossible to import many labourers from neighbouring districts owing to 'the sinister reputation of the Terai.'

In 1920, a few Pathans from North-Western India were brought down by contractors at attractive rates of pay, but this class of labour was found unsuitable, and an outbreak of severe malaria along with some cases of relapsing fever and cholera resulted in their absconding in large batches and the closing down of the work for that season. Lieut.-Col. W. A. Mearns, I.M.S., in an inspection report at that time points out that it was impossible to inculcate habits of cleanliness into these Pathans, and to the urgent entreaties of his staff that the Pathans should wash themselves regularly, the Pathan reply was 'this is not our bathing season.' As force could not be employed even in the presence of relapsing fever or cholera, it is obvious, as Colonel Mearns remarks, that the problem of controlling disease was beset with innumerable difficulties.

In subsequent years the bulk of the labour was brought by one contractor from the Bundelkhand area of the United Provinces and from Rajputana, in the month of November (after the Diwali festival) each year. A certain number of petty contractors employed coolies recruited from the neighbouring districts, and from among the hill tribes who used to come down for work during the winter months, and return to the hills in February of each year The date of the termination of each working season was variable and, except in the early years, was not dictated by illness. Some of the labour left for their homes at the Holi festival early in March, that indicating the date on which they had to begin reaping the Rabi* crop and preparing their fields for the Kharif* crop The hill men having departed before this, the main bulk of the remaining labour consisted of the coolies recruited from the Bundelkhand and these remained until they were sent home by their contractors at the end of the season. The work officially closed in May or June in the various years. During the monsoon a variable number of men, approximately averaging 100 each season, had to be kept on the work, and these unfortunately formed a reservoir of infection for the next working season.

(2) Owing to recruiting and administrative difficulties it was impossible to turn away labourers. Although attempts were made to find out those who would form the natural reservoirs of infection, the fact that no compulsion could be used and that the Indian labourer will not take medicine unless he actually has fever, precluded the possibility of any effective sterilization of this reservoir. On an average approximately 25 per cent of the labourers imported from the plains after the rains, were found to have enlarged spleens, while the percentage of enlarged

* The *rabi* crop is sown in winter and reaped in spring; the *kharif* crop is sown in summer before the monsoon and reaped in autumn after the monsoon.

spleens in children under 5 years brought in by their parents, was approximately 60 per cent.

In October and November 1926 the spleen rates of children and labourers brought into camps worked out at 41 and 23·7 per cent respectively (80 children and 350 labourers examined) while the figures for November and December 1927 were as follows :—

	Number examined.	Percentage with enlarged spleens.
Children (ages 2–5)	22	61
Children employed on works (ages 8–15) .	190	37
Labourers from the plains	425	28
Labourers from the hills	220	16

The parasite rate in acute infections was 85 per cent (crescent infection 28 per cent) and in cases with hard spleens was 9 per cent (crescent infection 6 per cent).

(3) The chief contractor was each year able to bring in a fairly large percentage of those labourers who had been to the headworks in the previous year but he also had to recruit from fresh areas. Thus regular streams of non-immunes from non-malarious areas were brought in with the old labourers, many of whom had enlarged spleens. The ' labourers ' were not only adult men and women but also children. No record appears to have been kept of the number of children employed but children from 8 to 14 years of age were constantly employed on earth works. In addition, large numbers of old people and small babies and children under 7 years were annually brought into camp by their relations or parents. This was unavoidable.

No attempt was made by contractors to keep children, old people or pregnant women off the works, and it was a common thing to see infants wrapped up in rags, placed in the shade among stones in the river bed, while their mothers were working as coolies.

(4) The population returns was submitted by contractors weekly to the Executive Engineer, but the accuracy of these is doubtful, as no check could be made to see whether contractors really were employing the number of men shown on their rolls. The error, however, is approximately constant throughout the years, as far as the malaria staff could estimate. It is also unfortunate that almost any one who came into camp and could work was given employment. The whole question of the collection of accurate statistics was rendered exceedingly difficult by the fact that contractors, perhaps naturally, were constantly complaining, especially when the work was being pushed, that large numbers of their men were sick, although hospital records did not confirm this. When comparing the statistics it must also be remembered that the labour population only takes note of those actually on contractors' rolls, while the sickness figures include these plus children and old people, and all Government employees and their servants, viz.,

all reporting sick in the camp areas. This error was estimated to be as high as 10 per cent in 1927, but has to be ignored as no accurate figures are forthcoming.

The statement showing the labour population in the working seasons of 1920–29 is given below, but, except for showing an increase in the possible working days until the canal was opened in December 1928, conveys no information as to the population present in the malarial seasons, which is, however, given in Graph V.

Years.	Number of working days.	Daily average labour strength.
1920–21.. ..	219	1,159
1921–22.. ..	243	1,616
1922–23.. .	226	2,127
1923–24.. ..	274	1,440
1924–25	242	2,185
1925–26.. ..	242	2,821
1926–27.. ..	334	2,567
1927–28.. ..	336	4,106
1928–29 . ..	273	2,497

XI. The Seasonal Variations of Anophelines.

Anophelines and their relation to malaria.

The following species of anopheline mosquitoes occurred in nature in great numbers, and it will be seen that the list includes practically the whole of the anophelines as yet recorded in the foot-hills and plains of the United Provinces :—

(1) *A. fuliginosus* Giles, 1900.
(2) *A. fuliginosus* var. *adiei* James and Liston, 1911.
(3) *A. listonii* Liston, 1901.
(4) *A. minimus* Theobald, 1901.
(5) *A. minimus* var. *varuna* Iyengar, 1924.
(6) *A. willmori* James, 1903.
(7) *A. maculatus* Theobald, 1901.
(8) *A. maculipalpis* var. *indiensis* Theobald, 1903.
(9) *A. culicifacies* Giles, 1901.
(10) *A. barbirostris* Van der Wulp, 1884.
(11) *A. turkhudi* Liston, 1901.
(12) *A. stephensi* Liston, 1901.
(13) *A. jamesii* Theobald, 1901.
(14) *A. subpictus* Grassi, 1899 (*rossii* Giles, 1899).

It is remarkable that at the very beginning of the work *Culex* mosquitoes were practically non-existent but with the opening up of the forest and construction of the camps a certain number began to appear. They never, however, became numerous, it being the exception to be able to catch ten culicines for every 500 anophelines. The chief breeding places of these culicines were defective soakage pits and swamps contaminated with fæces.

XII. Typical breeding grounds of the various anophelines.

A. fuliginosus, the most common species, was found breeding in every type of water, pure and contaminated, stagnant or slowly moving, which existed in the area. The favourite breeding grounds were pools, swamps overgrown with grass and weeds, rice fields, in sugar-cane brakes and in sunlit pools in the jungle. Larvæ were constantly found in still water highly contaminated with excreta. This mosquito mainly bred in the months of October, November and in May and June, whilst the variety *adiei*, no specimens of which were ever bred out in the laboratory from larvæ, was caught in nature specially during January in each year.

A. listonii. The larvæ of this species were most frequently found in various clear hill streams, ravines and in backwaters of the Sarda river, both in grass-grown areas and behind boulders in relatively swift flowing current. They were also found repeatedly in the seepage holes in the sides of some concrete anti-malaria drains which had been badly designed. An unsuspected source of these larvæ proved to be the edge of certain backwaters and stone- and boulder-strewn areas in the river bed in which the labour was working at pile-driving when building the barrage. The larvæ were never found in completely stagnant pools or swamps. The larvæ were most numerous from September to the beginning of November, but were found in small numbers up to the middle of March yearly. In the beginning of October large numbers were found in the small streams trickling from seepage outcrops.

A. minimus. Before 1925 no attempt was made to separate *A. minimus* from *A. listonii*, but when this was ultimately done it was found that *A. minimus* only appeared in the late autumn and invariably disappeared before the advent of the hot weather. After the December and January rains large numbers were bred out from larvæ collected from the grass-covered edges of the smaller streams.

A. willmori. This species could always be found in huts and the larvæ were mostly associated with sluggish streams and badly kept drains specially in the months of November and December when the annual working season was well commenced. Larvæ had a distinct preference for water exposed to sunshine and the less contaminated swamps beneath the cliff and behind the main labour camp. *A. willmori* larvæ were in no instance found alone, being always associated with the larvæ of *A. maculatus*, *A. listonii* or *A. culicifacies*.

A. maculatus. The larvæ of this species were never found before the middle of November nor after the beginning of April. Larvæ were found to occur in both small and large, exposed, uncontaminated pools and in narrow, relatively fast-running

streams obstructed with boulders. The absence of grass and vegetation would not appear to be a necessity for the prolific growth of larvæ of this species. No larvæ were ever found in shaded jungle streams or pools, nor in the pools in the sand of the river bed, though these might have been expected in the clear uncontaminated sand pools above the construction area.

A. maculipalpis. This species also occurred throughout the whole year, and larvæ were found in small numbers from October to the end of April in both stagnant or very slowly moving, grass-edged waters, specially in shallow marks, footprints and seepage pools exposed to light. Larvæ apparently were never found in actual seepage channels or streams or drains.

In March and April eggs of this species, as well as those of *A. maculatus* and *A. culicifacies*, were found to be breeding out into the imagos in under six days.

A. culicifacies. Larvæ of this species were never found in very large numbers even in April, when adults became relatively numerous. The larvæ could not be said to show a preference for any special type of clean water, but occurred in small numbers throughout the whole area, especially after the short storms and desultory rains in February and March. No larva or adult of this species was ever found between the end of November and the beginning of February in any year.

A. barbirostris Larvæ of this species were found in very small numbers in densely covered jungle swamps after the rains, and disappeared as soon as the undergrowth was cut and the winter set in. In very few instances was it possible to rear the larvæ into adults in the laboratory.

A. stephensi. This species was found only on a few occasions in rain water pools and in some of the wells in the villages surrounding the camp. It was not found in any of the rain water pools which were constantly being formed in the newly-made bed of the canal.

A. turkhudi. Larvæ of this species were never identified and only one adult was caught on the occasion of one of the first surveys in 1920–21. It is almost certain that this specimen was wrongly identified. The same also applies to *A. jamesii.*

A. subpictus formed approximately 1 per cent of the adult catch in the winter months and 5 per cent in the hot weather.

XIII. Seasonal prevalence of the various species of anopheline mosquitoes.

(1) Great variations occur in the relative numbers of the various carrier anophelines present in the area. In all cases, except one (*fuliginosus*), unless *A. minimus* be regarded as a variety of *A. listonii*, or both are considered to be Asiatic varieties of *A. funestus*, only one curve occurred for each mosquito in the year. The rise and fall in the various curves merge as a rule into each other. It is peculiar that *A. culicifacies*, which is by far the most important carrier in the plains of the United Provinces both in the spring benign tertian season and the autumn malignant tertian season, was entirely absent from this tract in the very cold weather from the end of November until the beginning of February

Considering the seasonal variations broadly, the various anophelines could be grouped together into autumn, spring or summer groups, which phenomenon must necessarily be related to a common group reaction to varying climatic conditions. It is obvious that each of the species in any one group does not bear an equal relation to the spread of malaria in that season. To begin with, during the month in which the anti-malaria works were being carried out preparatory to the arrival of the main body of labourers (viz., late in September and the whole of October), *A. listonii* began by forming about 60 per cent of the total daily adult catches and about 40 per cent of the larvæ bred out daily; while *A. fuliginosus*, *A. willmori* and *A. maculipalpis* were very soon found in such numbers that the adult *listonii* dropped to about 30 per cent of the daily catch and *A. fuliginosus* became the prevailing type, followed closely by *A. willmori* and to a much lesser extent by *A. maculipalpis*. In the winter the species in order of frequency were . *A. fuliginosus* (about 40 per cent), *A. willmori* (about 30 per cent), *A. maculipalpis* (about 13 per cent), *A. listonii* (about 4 per cent) while in December *A. maculatus* and *A. minimus* began to appear for the first time. In February *A. listonii* dropped in numbers but continued to form about 1 per cent of the mosquitoes caught up till the beginning of July, when its curve again rose when the rains had set in. The spring group of mosquitoes in order of frequency were *A. willmori*, *A. fuliginosus*, *A. maculipalpis*, and *A. maculatus*, while in the month of March *A. minimus* began to disappear and *A. culicifacies* to rise very rapidly, especially if the onset of the hot weather were rapid. If the *maculatus* curve be superimposed on the *willmori* curve as was done in the earlier years of the work when *maculatus* was not separately identified, it will be seen that this combined curve rises very rapidly from the end of February, if not from the end of December onwards, and ultimately these combined species form about 50 per cent of the total carrier anophelines.

The onset of hot weather conditions indicated a very steep rise in *A. culicifacies*, the *fuliginosus* curve which had fallen from February to April, rising parallel with the *culicifacies* curve in May, while during the hot weather the numbers of *A. willmori* and especially of *A. maculipalpis* and *A. maculatus* rapidly decreased.

With the onset of the early rains in June the *fuliginosus* curve remained steady, the *culicifacies* curve fell, while the decrease in *A. willmori* continued and *A. maculipalpis* and *listonii* again began breeding rapidly.

(2) It will be seen from Graph III showing the monthly distribution of malaria cases that the autumn malaria was probably mainly due to *A. listonii* and the spring malaria due to *A. maculatus* and *A. culicifacies*; these three mosquitoes being notorious carriers of parasites.

The malaria incidence as represented by these curves resembles that of the plains of the United Provinces, while the incidence curve of malaria in the 'Terai' tract does not tend to fall so quickly at the end of the malaria season, but to remain at a higher level throughout the winter months, and finally to be complicated with a rise in the malarial pneumonia incidence. This may be explained by the fact that in the 'Terai' generally the *listonii* curve does not fall rapidly until the end of

December, while *A. culicifacies* forms about 5 per cent of the adult catch until the end of December and *A. minimus* begins to appear in numbers in the end of November.

From these curves it would seem that *A. fuliginosus, A. maculipalpis* and *A. willmori* (when *maculatus* is separated from it) play little, if any, part in the transmission of malaria though, from the literature, they have all been experimentally infected.

Of the carrier anophelines found, *A. listonii* and *A. culicifacies* occurred in large numbers in dwellings and both bite during the day as well as at dusk and night. *A. maculatus* and *A. willmori* also both occurred—the latter in large numbers—in dwellings, and both readily bite during the night and at dusk. *A. fuliginosus* was ubiquitous, and with *A. maculipalpis* occurred in labourers' huts, but neither were observed to bite man except during the night. *A. listonii* and *A. culicifacies* were the most voracious feeders on man.

It is surprising that out of the many thousands of anopheline mosquitoes dissected by the malaria officers at the headworks prior to 1926, in no case had oöcysts or sporozoites been discovered to occur in nature. The dissection work in this area became so disheartening that no detailed records of species dissected appear to have been kept. This is the more remarkable when considering the dissections made in November and in May and June, when *A. listonii* and *A. maculatus* and *A. culicifacies* might reasonably have been presumed to show a relatively high infection rate.

From the working season 1926–27 onwards about 1,700 dissections were performed by the malaria officers in rotation. The results of these are compared with the results of other workers as given by Covell (1927).* Gut infections with oöcysts are not recorded, as immature oöcysts may have been missed and in any case oöcysts findings do not necessarily mean that a species is a carrier in nature.

The present negative results are thus not remarkable. In fact had any figure approaching the high result of some workers been observed, it would have proved carelessness, especially in the work of fumigating all buildings, whether permanent structures or huts, at weekly intervals. It is extremely unlikely in these conditions that many of the mosquitoes caught in camp would have been of a sufficient age to show oöcysts, far less sporozoites. It is possible that, especially in the benign malaria season in the spring, direct transference of parasites from man to man by mosquitoes might have occurred.†

That infections did occur in camp is undoubted, though the possibility of infection occurring in the late evenings or early mornings when coolies were working on the river bed, or were at other times visiting the surrounding villages, was an uncontrollable factor and was proven to have been the probable cause in many cases.

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* Covell (1927): "A critical review of the data recorded regarding the trnsmission of malaria by the different species of anopheles," *Ind. Med. Res. Memoirs*, No. 7.

† Mayne, Bruce (1928), *Ind. Jour. Med. Res*, XV, 4, pp. 1067–1072.

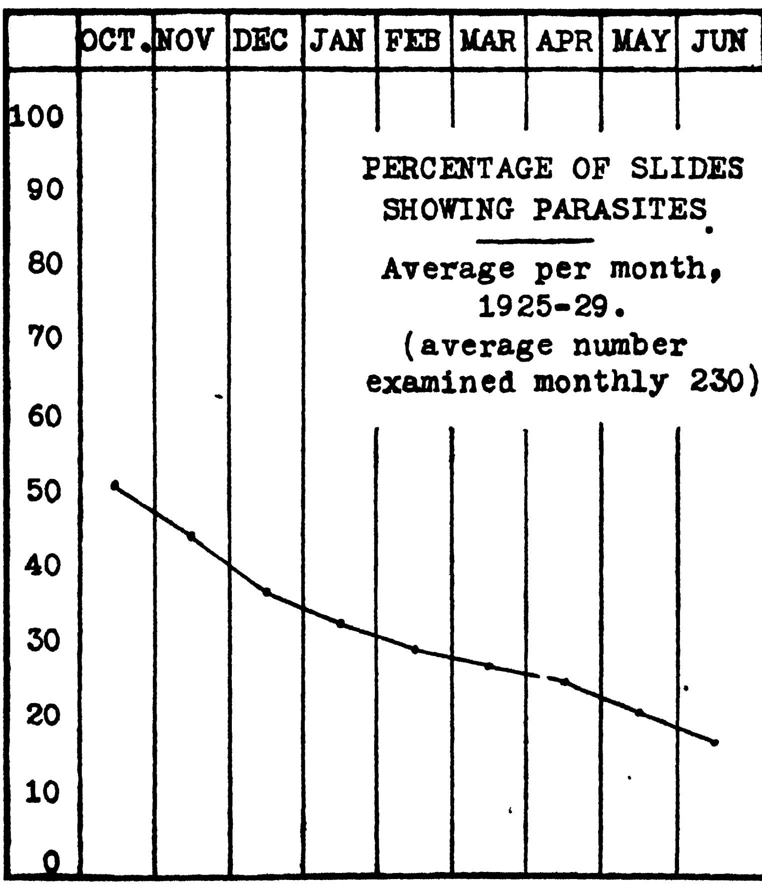
Species.	Total number dissected.	Percentage with sporozoites.	Observers and remarks.
A. culicifacies ..	1,893	0	Perry, Lalor, Fry, Graham, Kenrick, Rao, Horne, Gill, Singh and Carter, Stephens and Christophers, Graham, Ross, James and Gunasekara.
	3,338	0·5 to 8·6	Hodgson, de Sousa, Kenrick, Horne, Rao, Mhaskar, Sinton, Iyer, Krishnan.
	25	10	Cornwall.
	75	0	Present observations.
A. fuliginosus ..	2,518	0	Stephens and Christophers, Graham, Lalor, Bentley, Perry, Horne, Kenrick, Mhaskar, Gill, Shortt, Carter, Walch and Soesilo.
	23	4·3	Highest observation, Stanton, Malaya.
	350	0	Present observations.
A. listonii ..	507	0	Ross, Perry, Kenrick, Fry, Mhaskar, Rao, Carter.
	229	1·8	Perry, 1914.
	30	6·6	Horne, 1914.
	315	3·8	Chalam, 1923; Strickland, 1929, gives the figure at 3·5 per cent infected in nature.
	460	0	Present observations.
A. maculatus ..	149	0	Stephens and Christophers, Schuffner, Swellengrebel, Shortt, Carter.
	352	3·2 to 21·0	Watson, Stanton, Barber, Hacker, Essed, Doorenbos. Highest figures, Malaya and Dutch East Indies.
	60	0	Present observations.
A. maculipalpis ..	19	0	Perry, 1914; it is regarded on insufficient evidence to be a carrier in nature.
	35	0	Present observations.
A. minimus ..	64	6·2	Stephens and Christophers.
	81	1·2	Lalor.
	25	4·0	Iyengar.
	40	2·5	Present observations.
	70	0	Present observations.
A. willmori ..	..	..	Adie, 1911, records sporozoites in mosquitoes caught but gives no details. No other data.
	550	0	Present observations.

Another uncontrollable factor, interesting in view of the American work on mosquito migration, was that after days on which only young mosquitoes were being found in huts, catches of mature adults would be made, especially in the huts in the main camp on the river. This was put down to defective anti-mosquito work, but as it occurred mainly in the calm still weather in April, may have been due to evening migration down the Sarda.

XIV. Blood examinations.

In spite of the importance of finding out the labourers who harboured the sexual forms of the malaria parasites early in the season, it was found impossible

Graph I.

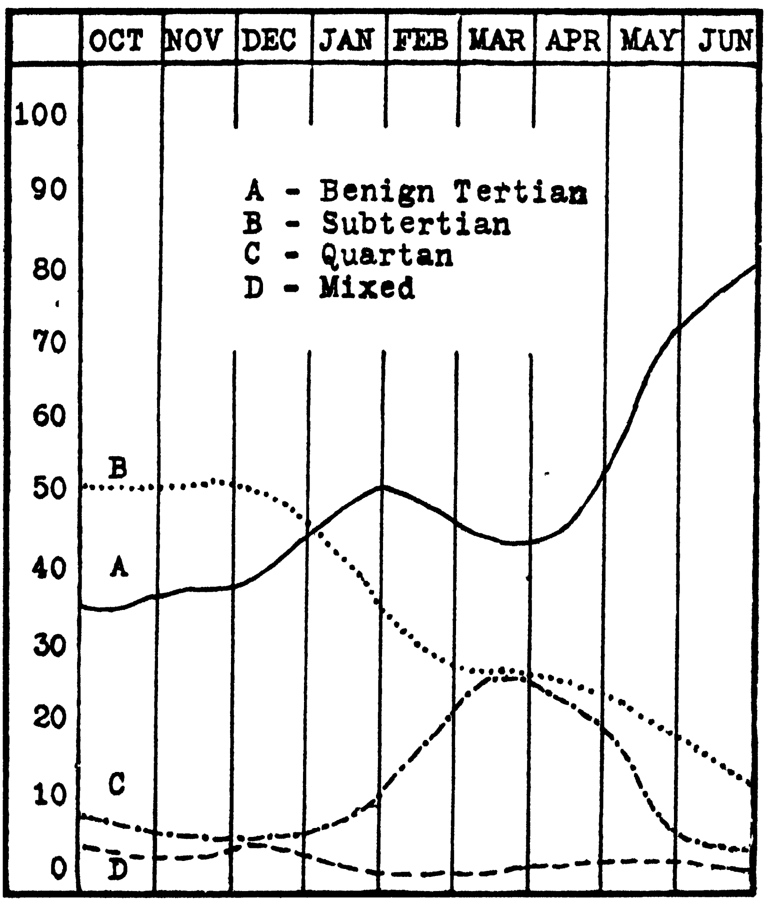


to obtain blood slides of the various labourers as they were detrained, or as they walked into camp from all sides at the beginning of the working season. Attempts to do this met with great opposition and of necessity had to be abandoned. It was

also impossible to persuade contractors to send the labourers who were infected with the sexual forms out of the camp, since the contractors would lose the money which is invariably advanced to all imported labour before leaving their homes. In practice, therefore, although attempts were periodically made to estimate the human reservoir of infection, the blood slides examined consisted mainly of those

GRAPH II.

Monthly variations in species as a percentage of total positive slides, 1925–29.



taken from patients presenting themselves at the hospital as suffering from fever. Even this was strongly resented owing to the ignorance and prejudice prevailing amongst the various classes of labour.

In the years 1922, 1923 and 1924 all slides were made by the thin film method, stained with Leishman and examined for 15 minutes. From the autumn of 1925

thick and thin films were taken on the same slides, the thick films being examined for five minutes each. Owing to the recognized inaccuracy of the thin film method the figures from 1925 onwards only are given in the Graphs. Giemsa was found to give better results than Leishman in the summer months.

The percentage of slides found to be infected was invariably highest in October and November and lowest in May and June, except in the years 1922 and 1926. The annual average of films found to contain parasites decreased from 36 per cent in 1922 to 24 per cent in 1923, presumably on account of vigorous anti-malarial measures. With the introduction of the thick film method, the percentage of slides showing parasites rose to an annual average of from 31 to 37 per cent. Although the graph represents slides taken from presumed new cases, it is obvious from the low percentage found infected that very large numbers of these could not have been new infections, but relapses in cases which had taken insufficient quinine. The low results in the benign season are noteworthy.

Infection with *P. falciparum* predominated throughout 1922 and in the autumn of each year at the time when the labour was coming into camp. In the autumn of 1925 the *P. vivax* infection percentage almost equalled that of *P. falciparum.*

Multiple infection of cells with as many as 3 or 4 parasites was the rule instead of the exception in the slides examined at the beginning of the working seasons, and the rings found were very frequently more minute than the *falciparum* rings described in the usual textbooks. Although the size of the crescent distinguished the infection from *P. quotidianum* Craig, 1909, the clinical symptoms observed by Craig were often encountered, and are well within the normal variations seen in severe subtertian malaria.

The benign tertian infection began to show a true increase in the spring of each year, except in the spring of 1922 when subtertian predominated. Quartan infections became numerous towards the end of each winter, and fell rapidly during the hot weather, while mixed infections formed approximately 2 per cent of all the positive slides and consisted almost invariably of mixed *P. falciparum* and *P. vivax* parasites.

XV. Anti-malaria measures.

Certain of the anti-malaria measures require to be mentioned in more detail.

Owing to the difficulties encountered from time to time, almost all the known measures, direct and indirect, were at one time or other undertaken. Of the anti-larval methods, jungle clearance. draining, filling, oiling, the use of larvicidal fish and, from October 1926, the use of paris green in place of oiling were tried ; of methods for the destruction of adult mosquitoes the burning of jungle grass, mosquito trapping, fumigation and the use of sprays were carried out. The methods for the protection of the healthy from mosquito bites were little used. The bulk of the labour had no protection whatsoever, except, perhaps, the one used from time immemorial by the Indian coolie of sleeping completely covered by his blanket and this, in the hot malaria season, could not be endured. Screening was not

carried out; fans were only provided for certain officials' bungalows, and only the more educated officers could be relied upon to use mosquito nets.

The treatment of malaria cases was carried out as thoroughly and as carefully as Indian conditions permit and will be commented upon later, while quinine prophylaxis, which formed the only method of protection available in the early years, was continued until the end during each malaria season, as a means more of mass treatment than of prophylaxis.

(*A*) *Jungle clearance.*

The jungle clearance work done was, as has been before mentioned, the cutting down of elephant grass, reeds and scrub jungle in low-lying lands and marshes, and subsequently setting fire to this material when it had dried sufficiently. This work in the first few years was done by the anti-malaria gangs, but it was later found to be more economical and expedient to contract for the work. The scrub jungle surrounding the camp and on the islands in the middle of the camp area was not cut, except in the fire lines as a protection against forest fires, and it is certain that in small areas which had been cleared by villagers anophelines appeared where previously none had existed. Elephant grass jungle, however, had to be cleared even after the introduction of the use of paris green, not only to destroy the adult mosquitoes harboured by it, but also, because the swamps and streams under this scrub were breeding profusely, to allow of efficient oiling or the more economical use of paris green and to facilitate free drainage and the drying up of sodden ground.

The cost of this jungle clearance around the main camp by the anti-malarial gang, as given below, cannot entirely be put down to anti-malarial measures, as it includes some of the cost of clearing stretches on higher land for sanitary purposes. It should also be noted that this does not include the main jungle clearage done by the engineers. For this an estimate of approximately about Rs. 10,000 was sanctioned every year after the forest had been cleared.

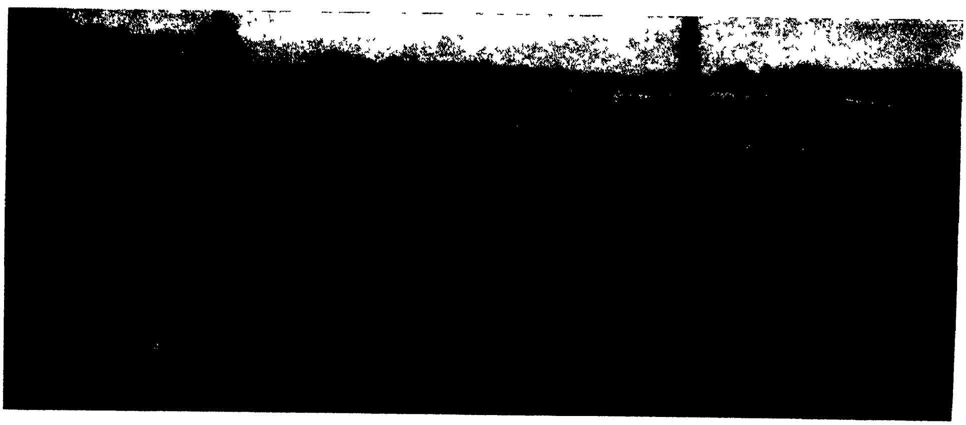
1920–24	figures not available.
1924–25	Rs. 1,128
1925–26	„ 1,788
1926–27	„ 2,559
1927–28	„ 2,168
1928–29	„ 4,129

(*B*) *Drainage schemes.*

The alignment of the temporary drains had to be altered from time to time, not only owing to the fact that each successive rainy season saw the drains destroyed and wash-outs created in the vicinity, but also because the topography of the area became gradually altered as the various earthworks and engineering schemes advanced. It was, therefore, impossible until comparatively late in the work to press for the construction of the permanent anti-malaria drains, which had been given in the original recommendations of 1919 as one of the essential measures which must be undertaken. Previous to these permanent drains being laid down,

PHOTOGRAPH 4.

No. 1 marsh and seepage area, as in October yearly after preliminary jungle cutting until 1927.



No. 2 jungle cutting, October 1928, after permanent drains had been constructed.

No. 3 head of marsh at Right Afflux bund, November 1928.

as the cost and difficulty involved in keeping the temporary drains free from vegetation, silt, etc., rose, it became necessary to line the sides of these drains. The sides were first pitched with boulders, but this was not a success owing to the enormous amount of breeding which occurred between the boulders and in wash-outs in the soft soil behind them. Another experiment, made by filling certain drains with boulders and covering them over with shingle, failed owing to the falling in of the top layers during the working seasons and the complete blocking up of the drains with silt during the monsoon, this necessitating the complete opening up again of the drains. The bottom of one drain was pitched with boulders and while this was partially successful in preventing the rapid growth of weeds, the sides broke down even more rapidly.

The most troublesome area to deal with by drainage was that between the cliff and the main channel of the river. This area consisted of several islands covered with tree jungle and separated from each other by low-lying marsh land, originally boulder-strewn and formed by the channels of the river, but now cut off from the river by the earthworks known as the 'right afflux bund and guide wall.' From the levels given on the map* it will be obvious that continual seepage was going on under this bund and indeed the whole of this marsh land required the most careful oiling or treatment with paris green every year after the monsoon until the water level had been reduced by remaking the drains. Although the relatively higher portion of this land dried sufficiently by January to render breeding impossible, seepage outcrops required continual attention by filling or by temporary measures until 1927, when subsoil drains were laid down. From the survey plan of anti-malaria drains* it will be seen that there were six main 'kachcha' drains in this area extending approximately to 4 miles in total length. Over 15,000 feet of these drains were made permanent between May 1927 and June 1929, at a cost of Rs. 68,000 The type of permanent drain made was the usual semi-circular invert of concrete in 6 feet lengths with seepage holes at the lowest point along the drain. Originally seepage holes were made in the sides, and these formed most excellent breeding places when the drain was running half full during the spring benign season. The spaces between sections were filled in with cement and spaces left at the lowest point. The sides of the drains above the inverts were pitched with boulders, which were faced with cement up to the normal October flow.

The experience gained with the earlier drains, which should have been unnecessary, completely confirmed the axiom that having decided the depth at which such drains should normally be laid, they should then be further lowered by several feet.

These drains ultimately combine to run in a siphon under the canal, from which they pass into the marsh which formed the Western boundary of the island on which the main labour was encamped. This siphon was built in 1924 and was fitted with a gate, but alternately raising and lowering the water-level in this area by shutting and opening this gate proved useless as an anti-malarial measure.

* It has not been found possible for financial reasons to reproduce these maps.—Ed.

Before the sides of the canal were built, this marsh to the west of the main camp was continuous with the low-lying area subsequently drained by these drains. A brick-lined drain was constructed in 1927 and 1928 down the edge of this swamp and drained the water of all the permanent drains constructed. It was, however, unable, as was expected from the very beginning, to make any impression on this marsh. As the river in this region is higher than the marsh level and the outlet of the marsh is about 1¼ miles down stream, it was considered impossible to deal with this problem at all, either by a system of tidal gates or earthworks, and the marsh continued to require treatment with paris green until the construction was completed.

Another notorious permanent breeding ground which required regular oiling or paris-greening, was the stream and ravine across which the canal cuts at 1 mile, 1 furlong from the head. This stream ran through the thick jungle to join the marsh above mentioned.

One of the worst breeding grounds was the Salani 'Got' channel. This is a broad arm of the Sarda which passes the Salani 'Got' village 2 miles above the headworks, runs through dense jungle and thence into the Sarda above and parallel to the right afflux bund. This channel spreads out into a number of small streams and creates extensive water-logged areas covered with elephant grass. Some six earthworks were built to divert this channel primarily with a view to silting it up and protecting the afflux bund, and thus the canal, from damage in the floods. The reduction in the volume of water and the partial silting up, complicated instead of assisting the malarial problem, in that areas previously covered with water not breeding mosquitoes became shallow swamps which bred profusely. This area was within half a mile of the camp on the cliff and, as it was not shut off from it by forest and was one of the chief breeding places of *A. listonii* it required regular treatment until the headworks were completed. Regularly at the beginning of the working season every year as much of this area as practicable was cleared of reeds and the channel connecting it to the river deepened, but drainage schemes were found totally inadequate.

(*C*) *Oiling.*

This was carried out from the year 1921 to the end of 1925-26 season when it was replaced by paris green. The want of sufficient gradients, the extensive creation of pits, etc., during the construction work and the erection of earthworks, both permanent and temporary, for the laying down of trolley lines throughout the camp, made drainage impracticable in many cases.

The usual routine was laid down that each of the seven sections into which the camp areas and environs were divided would be systematically oiled on the same day each week. The initial oiling after the cutting down of jungle grass was wholesale, but subsequent to this, only known breeding places were marked on the maps and oiled. The efficiency of oiling was ascertained by examining each area 24 hours after it had been oiled and re-oiling if necessary. A second squad was deputed to keep drains clear of weeds and silt.

PHOTOGRAPH 5.

No. 6 swamp, October 1926

The same, October 1927.

The mode of oiling was chiefly by means of a mass of tow tied to the end of a bamboo stick, but other methods such as using a broom dipped in oil for sweeping over a sodden area, using the ordinary oil sprays, burying tow soaked in oil under the head of seepage areas and using drip cans, were employed when required. The composition of the oil was varied from time to time. At first only kerosene oil was used, but this was found inefficient when used by coolies, non-lasting and expensive. Crude oil was also found to be too expensive, as its spreading power was very low. A mixture of crude oil 98 per cent with 2 per cent castor oil was tried, but was given up for a mixture of crude oil 75 per cent, kerosene oil 20 per cent and castor oil 5 per cent.

Cresol proved less effective and more expensive for even the shallowest waters than the crude oil, castor oil and kerosene mixture. The Panama larvicide, prepared according to the original specification, proved more expensive, and did not retain its larvicidal qualities sufficiently long. 'Empranin,' 'Pesterine' and the other proprietary larvicides tried were less efficient and more costly than the 'oil mixture' in general use. Oiling was usually found necessary once a week from October until 15th December, and once every 10 days from 15th December to 1st March, when weekly inspections were again commenced. While certain breeding grounds required oiling at these regular intervals it was found that on others the oil remained and was effective for long periods, and in the hot weather relatively little oil was used as the breeding areas became more localized.

(*D*) *Filling.*

The filling work which was carried out was mostly of an experimental nature, and was found on the whole to be unsuccessful, owing to the reappearance of seepage outcrops in the filled areas, and the enormous cost involved in filling up to the height necessary to abolish these.

In only two areas under the cliff, in the region of drains Nos. 2 and 3, was filling found successful. Details of the cost of this experimental filling from 1920 to 1923-24 is not available. In the working seasons 1924 to 1926 Rs. 2,900 were spent in filling the two areas above mentioned. In the working seasons 1926 to 1929 the cost of certain filling operations in connection with the laying down of subsoil drains amounted to Rs. 2,700.

(*E*) *Use of paris green.*

In October 1926, the system of anti-malaria work was altered by introducing paris green to the total exclusion of oil, and concentrating upon this and fumigation as the sole methods used in conjunction with treatment. It was obvious from the literature that paris green, introduced first in 1921 and reported upon by Hackett at the International Malaria Congress in Rome in October 1925, was specially suited to the conditions prevailing in the headworks area, and in practice it was found that more efficient control was possible, even with an apparently careless use of paris green than was possible with the most careful supervision of oiling.

In October 1926, a 1 per cent dilution of paris green in dried road dust—which contained a high percentage of sand in this locality—was spread by hand over the marshes and known breeding grounds of the year before, after which jungle cutting was commenced. While at first the quantity used was 1 c.c. paris green to approximately every 100 square feet of surface, it was soon found that considerably less could be used, especially in the *A. listonii* season, and when the swamps had once been cleared a 1 in 200 dilution was found ample to control breeding, except against *A. fuliginosus* and *A. willmori*. As both these mosquitoes probably played no part in raising the malaria incidence, a dilution of 1 in 200 would probably have been ample until the beginning of the *A. culicifacies* season when a 1 in 100 dilution again became necessary.

Paris green had to be used once every seven days from the end of September to the end of November, and in March and June, while from December to February the intervals were increased to once every fortnight. The weekly spreading in March and June could have been extended to once every nine days, had it not been for the breeding which occurred in seepage outcrops.

The use of sand as a diluent over the areas covered with reeds and jungle grass gave better results than the use of dried dust, and in addition, as is to be expected, killed culex larvæ in greater numbers. Mixing was at first done by hand and later in a box 'mechanical mixer,' but the use of blowers was found to be unsatisfactory in the hands of coolies. It was given up after a short trial for the ordinary method of throwing the mixture by hand. Used in this way by unskilled labour, once the mixing had been thoroughly done, results were immeasurably more satisfactory than with oil.

With the use of paris green it was unnecessary to carry out extensive jungle clearance as an anti-malarial measure, except where this facilitated the draining and drying up of marsh land.

The carrying out of anti-larval measures in the Terai would be absolutely impossible, if the flight of any of the carrier mosquitoes found there approximated the range of *A. maculipennis* in Europe. To make the problem practicable at all, advantage was taken of belts of thick jungle, which screened off various camps, and while thick jungle in which the undergrowth was uncut apparently formed effective screens in the cold weather, this did not appear to be so in the spring. For purposes of using paris green, it was assumed that all breeding grounds within three-quarters of a mile of aggregations of labour, camps, etc., required to be treated unless screened off *effectively* by trees.

None of the anti-malarial gangs at any time showed any signs of arsenical poisoning and paris green had no effect on the larvicidal fish with which the area abounds.

Considerable difficulty was experienced in obtaining supplies of paris green in India of a guaranteed strength of 50 per cent arsenic and a guaranteed fineness of 303 D. In 1926 paris green had to be imported from Europe.

PHOTOGRAPH 6.

Main drain in seepage area No 4 in mid-October before and after laying down permanent drains. These consist of semicircular concrete inverts with sloping cement sides surmounted by pitched boulders.

(*F*) *Larvicidal fish.*

The following larvicidal fish were found in large numbers in the area :—

1. *Barbus ticto.*
2. ,, *stigma.*
3. ,, *terio.*
4. ,, *phutunio.*
5. *Trichogaster fasciatus.*
6. *Trichogaster labiosus.*
7. *Badis badis.*
8. ,, *dario.*
9. *Nuria danrica.*

These fish could be found in all marshes and streams and were artificially introduced into isolated ponds and borrow-pits. They invariably found their way into all anti-malarial drains. Orders prohibiting netting were issued and certain waters policed to enforce the orders.

Each one of these species is recognized as of great value in destroying mosquito larvæ, and *T. fasciatus* and the smaller varieties of *Barbus* mentioned existed in such enormous numbers that, if all that is claimed in the literature for larvicidal fish is correct, there should have been no rise in malaria especially in the spring when the breeding places were practically confined to places where these fish were numerous.

It is extremely doubtful, in the United Provinces Terai at least, if larvicidal fish can be considered as of any use whatsoever. It is admitted that in ponds relatively clear of weeds and where mosquito breeding is not so intense as in the Terai, they are of some value, but although they find their way into every drainage cut and exist in such enormous numbers here, they are of themselves useless even where the stream edges are kept free from grass.

The question of predaceous fish destroying these larvæ did not occur in the waters considered, although *Barbus afghanus*, *Macrones tingra* and *Ophiocephalus gachua* occurred in the deeper waters.

(*G*) *Fumigation.*

The fumigation of permanent and temporary buildings was carried out at weekly intervals from 1926, and was found to be of the greatest importance, although it was distinctly unpopular with certain classes owing to persistence of the odour. Cresol, carbolic acid, sulphur, pyrethrum and tobacco leaves were tried. For routine fumigation a mixture of equal parts of sulphur and powdered waste tobacco leaves and stems were used for out-houses, store rooms, labourers' huts and menials' quarters. Contrary to expectations this fumigation was found to be of great value in the case of labourers' huts and shops made of grass and bamboos.

One half lb. of mixture per 1,000 cubic feet of air-space, burned quickly, was found to clear closed buildings of mosquitoes in 15 minutes, the usual procedure being adopted of collecting stunned mosquitoes in a paper placed under a window the glass of which was uncovered. In the case of labourers' huts the fumigation was performed at the hottest time of the day, when mosquitoes driven into the

open would be less likely to survive. In the case of the buildings occupied by residents who objected to fumigation with sulphur or tobacco, pyrethrum or cresol was used, or sprays made available. Of the numerous preparations available as sprays a mixture of carbon tetrachloride 1 per cent, creosote 2 per cent in kerosene oil 97 per cent was found most efficient.

(*H*) *Screening.*

During 1920 and 1921 while the preliminary surveys were being made to locate the sites of the works to be built and buildings were being constructed, everyone in camp lived in tents or grass houses, but it is unfortunate that when the stone houses were built for officers and overseers in 1923, they were not provided with mosquito-proofed verandahs. This was apparently not pressed by the medical authorities until much later when the works were nearing completion.

We have no evidence of mosquito-proofed huts ever having been provided for labour camps in India, but it is certain that a type of hut could be designed on the lines of the soldiers' barracks which have, in certain places, been rendered mosquito-proof. Without electricity and fans screened houses in the United Provinces Terai would be absolutely unbearable. The first intention was to run the pumps, etc., by electricity, but no firm could guarantee delivery of the plant before 1923. It became necessary then to install petrol pumps, but these gave trouble owing to the sand in the river bed blowing into the bearings. It was not until 1926 that electricity was available, and electric light and fans were at once provided for the superior staff. It is unfortunate that no suggestions were made at the beginning of the work that a special electric light plant should be provided. Had this been done and fans provided the houses of the Government officials at least could have been screened.

It is now our considered opinion that the provision of mosquito-proofed houses for all educated staff should be accepted as one of the first charges against any large engineering project in this tract. As to whether the provision of mosquito-proofed barracks for uneducated native labour would not have proved worse than the provision of grass huts is a debatable point. With properly designed doors, regular fumigation and an efficient system of inspection of the barracks, it is believed that the malarial incidence could have been more efficiently controlled had screened barracks replaced the grass huts.

There is no doubt that malaria in this camp was often, as James has pointed out, a 'domestic' disease. Repeatedly the occupants of servants' quarters would be attacked by malaria one after the other. This was especially evident in a large barrack near the power house, where 9 occupants out of 12 developed malaria within 4 days of the first going sick. while coolies in neighbouring dwellings remained free. On investigation it was found that this barrack was always kept locked when the men were on the works and had not been fumigated for three weeks.

XVI. Quinine prophylaxis.

It is to be remembered that the use of prophylactic quinine was really a mass abortive treatment—(fever abortive mainly)—and it was carefully pointed out to all concerned in the later years of the work that quinine prophylaxis, whether of cinchona febrifuge in the spring or quinine sulphate for the autumn malignant malaria, had to be ended by one complete week's treatment of 30 grains daily. This ' treatment ' was made available to all, but. while the coolies availed themselves of it to some extent, it was obvious from reports received and sickness returns that the Government staff were most careless in accepting this terminal treatment.

It proved completely impossible to control the treatment of the educated and semi-educated staff on the works, as they demanded to be given medicine to take to their dwellings, and no guarantee could be given as to how much quinine they consumed. This issue of quinine is admittedly necessary where quinine has to be provided for wives and families kept in seclusion by the ' purdah ' system, but it only resulted in an impossible situation when every one with any pretence to education or who had any official support demanded quinine in bulk It must, however, be admitted that the malaria season invariably coincided with the times when the whole staff and labour on the works were working at a very high pressure in difficult circumstances from dawn to dusk. and it could not be expected that at the end of the day they would go out of their way to obtain quinine if that could be avoided.

From enquiries made from labourers who returned to the works in succeeding seasons, it appears that they did not suffer from malaria when at their villages to anything like the same extent as did the contractors and engineering staff.

Quinine for prophylactic purposes was issued in a solution of 10 grains of the sulphate to the ounce. In the early years from 1921 to 1923 quinine sulphate in acid solution was given out to all on two successive days in each week during the autumn and spring months as soon as the fever admissions exceeded twice the normal daily average attendance. There were frequent demands from the canal officers, contractors and labour to supply quinine in pill form, and while these were not issued at first, from 1926 onwards pills were issued. The pills were made containing 4 grains each and 3 was the minimum daily dose. In practice 12 grains in pills proved as effective as the 10 grains in a mixture. The pills were made up fresh twice a week, as it had been found that two ' quinine resistant cases ' were passing stock pills in their fæces.

As the malignant tertian parasite was the most prevalent type of infection in the autumn and the benign tertian in the spring months, it was decided in 1924, in view of Acton's work at Dagshai, to substitute cinchona febrifuge in place of quinine sulphate for the spring malaria. The substitution was strongly resented by certain classes, who considered that an inferior product was being used to cut down the expenditure, and while a small quantity of cinchona febrifuge was issued, quinine was mostly used, in treatment and in prophylaxis, either alone or mixed with cinchona febrifuge. From February 1927 cinchona febrifuge was used exclusively in the benign tertian season and quinine in the autumn season for ' prophylaxis.'

Method of quinine prophylaxis.

It was arranged to distribute quinine on two days each week in each camp. The labourers were to be collected at the end of the day's work under their contractors, and respective subdivisional officers. It will be seen from the statement given (Appendix VIII) that the attendance was most erratic, but whenever the irrigation officers were able to supervise the parades, the number of men 'prophylaxed' was almost a hundred per cent. As soon as quinine prophylaxis was started the hospital admissions almost simultaneously went down and cases of severe and complicated malaria were greatly reduced. The number of weeks in each malaria season in which 'prophylactic' quinine should be given was carefully considered. As mass treatment and not prophylaxis was the aim, the issues were made annually from the beginning of the working season until the hospital outdoor figures began to drop. Had strict official control of contractors' labour been forthcoming this period would not, perhaps, have been so prolonged.

It is to be remembered that Government officials had no authority to force contractors' labour to take quinine. Any undue interference meant that labour absconded, and then claims for compensation were made by the contractors for advances still outstanding. Delays in completing the work were claimed to be due to interference with labour. Compulsion could not be used, and as the majority of labourers loathe quinine it is difficult to know how strict control could have been exercised.

In 1925 it was realized that it was useless to hold these 'parades' when so few turned up, and as there was no other method of making quinine freely available and men would not come to hospital, medical officers visited the men on the works during the day and made hut-to-hut visits in the camps. A certain number of cases who had not reported sick were always found lying sick in huts.

Those who accepted quinine on the works were mostly those who had recently had fever themselves, but who would never think of walking to any of the hospitals or dispensaries for it until they again relapsed.

It is also to be remembered that the Indian coolie will only take quinine when he actually has fever. Efforts to trace cases that had been diagnosed as malaria and had stopped taking quinine after two or three days, proved useless owing to the enormous labour involved. The Indian villager and coolie does not realize the need for a bacteriological cure of malaria, a temporary clinical cure which suffices to let him get back temporarily to his work being all that he desires. It is in any case useless, except for its effect on the 'carrier' reservoir, to attempt a parasitic cure when the cases are in a hyperendemic area.

The tables in Appendix VIII give the number of men prophylaxed, the daily average population and the percentage attendance from 1923 to 1929.

The fallacies in the table are obvious. To say that in a given week 48 per cent of the labour population was prophylaxed is erroneous, as there is no guarantee that the 48 per cent who received a dose of quinine or cinchona on the first day each week were the same people who received the second dose the next day. Efficient

mass treatment by parades is impossible unless the men are under official control, and no control whatsoever could be obtained over the contractors.

XVII. Vital statistics.

It is not proposed to claim more from the statistics than that the malarial incidence in a hyperendemic tract, proved in the first years of the construction work to result in the closing down of the works from epidemic malaria. was controlled to such an extent that it became possible to build the headworks. In the conditions existing no progressive decline in malaria could be expected each succeeding year. The variations in the figures of the various years can be considered as well within the normal limits due to climate and the other factors present, even when intensive anti-malaria works are being carried out.

The collection of statistics. specially in the earlier years owing to frequent changes in the staff and unsettled conditions, was far from efficient. The population figures, as before stated, only relate to the number of men actually on the contractors' rolls and do not include their families and dependents, the officers' servants nor the many subordinates who were employed in various capacities in connection with the construction. The hospital figures include all sick in the camps.

Owing to administrative difficulties and impossibility of controlling the daily immigration and emigration of labour throughout the working seasons, it was almost impossible to keep a check on the collection of the various data.

In later years with improved methods of registration and less frequent changes in the staff, the recording of statistics greatly improved. The credit of this is entirely due to Lieut.-Colonel Dunn, I.M.S., Director of Public Health, U. P. Taking into consideration that the system of administration and the type of recording agency was the same from 1923 onwards, it would appear that the errors of omission and commission are relatively constant. The figures therefore have a comparative value over a fairly long period, and in the computation of these statistics only those figures that have been recorded by authorized agencies have been taken into account :—

Statement I.

Banbassa Headworks Division.

Season.	Population (daily average).	Recorded sick rate per 1,000.	Recorded malaria sick rate per 1,000.	Crude death rate per mille.	Crude death rate for the whole district.	Malaria death rate.
1923–24 ..	1,440	..	..	88·19	29·75	27·90
1924–25 ..	2,185	28·43	8·19	28·37	28·76	27·49
1925–26 ..	2,821	21·44	7·86	45·01	29·22	27·36
1926–27 ..	2,567	7·68	3·19	42·46	32·43	30·62
1927–28 ..	4,106	12·43	3·74	40·72	29·17	26·29
1928–29 ..	2,497	14·60	6·40	32·40	..	..

(*A*) *Population.*

In the above statement the average daily population shows a gradual increase up to the working season 1927-28. As will be seen from Graph V giving the average monthly population figures, the highest figure reached was 9,486 in 1927-28, as against 3,401, 4,156 and 5,823 respectively in the previous three years.

Although the canal was run during the hot weather of 1928 owing to a partial famine in the province and was officially opened by His Excellency the Governor in December 1928, the work continued up to June 1929, and the peak of the labour population figure reached in this season was 3,760 (*see* Graph V, p. 109).

Up till the rains of 1925 the main body of labour went away each year, the works were closed and the place abandoned. During the rains of 1926, 1927 and 1928, a small permanent staff averaging from 113 to 195 per month had to be kept permanently on the works. As practically all these men contracted malaria in the rains, the high malaria incidence at the beginning of the later working seasons represents mostly relapses among this staff.

The first increase in the population figure in each working season represents the officers, malaria staff, overseers and the few labourers who were engaged on the initial work necessary before the advent of the main body of labour in November each year. The November rise in the graph is followed by a further irregular rise and subsequent fall, due to the continual arrival and departure of hill men and labourers from the surrounding districts. From 1926 onwards owing to the urgency of the work, labourers were imported from Bundelkhand in December and January as well as in November.

These population figures are too low for the reasons already given. The error was estimated at as much as 10 per cent in November 1927, but any correction of the data is impossible owing to the constantly fluctuating population.

(*B*) *Total sick rate.*

The attendance figures of the hospital and dispensaries show that the total 'new' cases varied from 28·43 per mille of the population in 1924-25 to 7·68 in 1926-27, and rose in 1928-29 to 14·60 per mille. These figures can no more be taken to represent only the 'new' cases than to represent the total morbidity, but are somewhere between these. Cases with minor diseases, almost invariably ceased attending hospital after one or two visits, and on their reappearance later could seldom produce their original outdoor tickets. This necessitated the issue of new tickets, as it proved impossible on account of the labour involved, the similarity of Indian names and the delay thereby caused to coolies and their work, to look up the registers and issue duplicates of the original tickets.

The total morbidity rate, as judged by periodic attempts to verify the data, varied from 5 per cent to 10 per cent above the recorded new sick cases. The highest error was from December to March, when very few malaria cases were occurring or relapsing after the malignant tertian season just over. The lowest error was towards the end of each working period in the benign tertian season, when the climatic

conditions and heavy pressure of work in the river bed made those cases which were taking insufficient cinchona febrifuge unable to carry on without reporting sick. As was to be expected the problem of benign relapses became serious in May and June each year, as men could not work in the heat when taking adequate treatment and went back to work as soon as they could, only to relapse in a few days' time. The new case figures in all years except 1926-27 also record, in many cases, the same labourers two or three times each month as new cases from April to June. No system of working is capable of obviating these errors entirely in busy construction camps run by contractors in India.

(*C*) *Malaria sick rate.*

The above fallacies also apply in connection with the graphs showing the total malaria 'new' cases and the ratio per mille of these cases. These graphs therefore represent new cases with a percentage of relapse cases included. The 'new' malaria cases fell progressively from 8·19 per mille in 1924-25 to 3·19 in the working season 1926-27, and again rose to 3·74 and 6·4 in the working seasons 1927-28, and 1928-29 respectively. The very high rates prior to 1924 in the short working season before anti-malarial measures were undertaken cannot be given, owing to the lack of accurate statistics.

The total number of malaria cases fell to a low figure during the months of maximum population. While this may partly be due to working on a progressively increasing population, the fact that the low rate continues in a hyperendemic malaria area can only be considered as due to the anti-malaria measures.

(*D*) *Corrected data*, 1926-27.

(*a*) *Malaria new cases.*— An attempt was made in the working season 1926-27 to record the actual numbers of fresh malaria infections and the number of relapses and it will be seen from Graph V that when this was done the new infections remained approximately at 1·0 per mille from January to April, rose to 2·0 per mille in May and further to 5·0 per mille in June. The subsequent rise brought the figure rapidly up to 35·0 per mille in July among the few labourers left in camp.

(*b*) *Malarial morbidity.*- The relapse cases added to these new cases (i.e., the malaria morbidity) rose to 900 in a population of 3.631 in December 1926, and included new infections, relapses after malaria contracted locally in the rains and in October and November, and relapses among newly imported labourers, who had contracted malaria before arriving in the camps. This malarial morbidity fell from January to March, reached a total figure of 240 in a population of 5,708 in the month of February, and 260 in an average population of 4,196 in March. As the benign season and severe hot weather conditions progressed, the figure again rose and the total sickness for malaria in May reached 1,100 in a population of 3,005 (between 30 and 50 per cent of these sick were still working daily). In June as the works gradually closed and the population figure fell, the malarial morbidity became

exceedingly high, reaching a figure of 400 continually relapsing in a population of 904. Between 30 and 50 per cent of these cases were still working.

This high malarial morbidity occurred each working season as is evident from Graph VI (p. 110), and it can be taken that approximately 80 per cent of the figures making up the April, May and June curves 'for total cases' yearly, were, due to relapsing benign malaria and its sequelæ. It is obvious from the verified graph of new malaria cases for 1926-27 that these relapses were mostly relapses of old cases and not of comparatively new infections, namely an increased rate of break down, due to the exhausting work and climate, of those benign cases which had been relapsing all through the winter, the ratio of which to malignant cases can be estimated from the graph giving the results of blood examinations.

(*c*) *New cases all causes.*—This graph runs almost parallel to the fresh malaria incidence graph and it will be seen that until June 1927, the 'new cases' other than 'malaria' almost equalled the 'new' malaria cases. From June benign malarial cases constituted practically all the 'new' cases recorded.

(*d*) *Total morbidity.*—The total morbidity graph for 1926-27 includes all 'new' and 'old' cases, relapses, etc. This does not mean that all the cases comprising this graph were too ill to work, the rule being, as has been stressed several times, that the Indian coolie will go out on the works if he possibly can, to avoid losing his pay. The practice of distributing quinine on the works is open to objection that it grossly encouraged this habit, but it was the only way to ensure quinine reaching these men.

It is obvious that owing to the labour involved in keeping these statistics for 1926-27 the procedure could not be continued in other working seasons, especially when the control of malaria on the Sarda was only part of the work of the malaria officers in the province. Any practice which delayed the labourers or hindered the work had to be dropped, although inability to carry out research of any value resulted.

(*E*) *Pneumonia incidence.*

The incidence and recorded death rates of pneumonia in all headworks camps are as follows:—

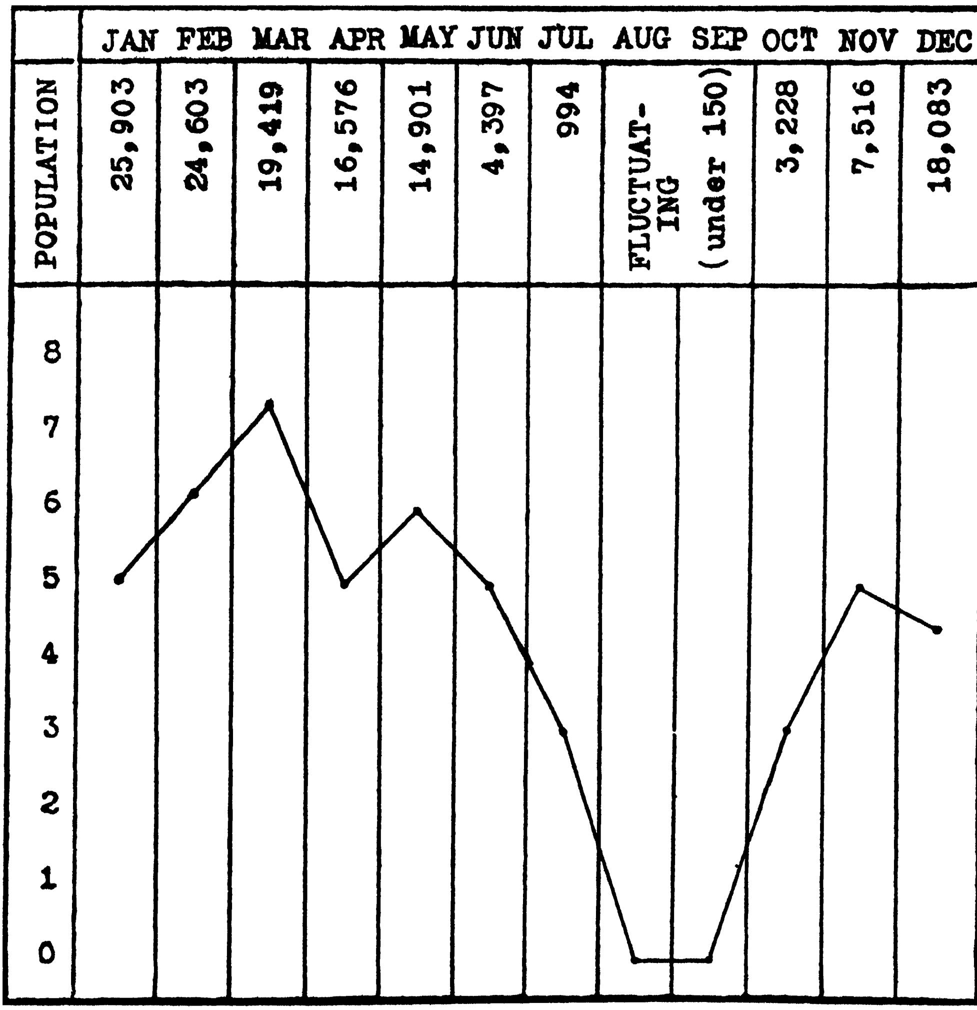
Pneumonia.

Year.	Total cases treated.	Deaths in cases treated.	Case mortality.	Deaths in camps. Cause verified as pneumonia.	Death rate in all camps.	Death rate for the district.	
						Crude reported.	Verified by medical agencies.
1925 ..	205	18	8·78	30	19·4	0·37	7·90
1926 ..	283	19	6·73	40	25·5	0·39	7·20
1927 ..	178	24	13·48	10	8·1	0·49	9·8
1928 ..	192	33	17·19	20	2·4	Not available.	
1929 (up to June).	61	1	1·64	11	5·9	Not available.	

The cases admitted to hospital were almost invariably detected in the camps by medical officers on their hut-to-hut visits. The opposition of the Indian to any separation from his family led to these cases being admitted mainly in the third and fourth day of disease. Eighty per cent of the cases not reported or detected in camp and resulting in the deaths in camp, were among children under 8 and adults over 50 years of age, and 50 per cent were in children under 10 years.

GRAPH III.

Monthly incidence of pneumonia per mille of population (*5-year period*, 1925–29).



Graph III shows the pneumonia morbidity rate per month for these years. The data is to be compared with the death rate as verified by professional agencies, and not with the crude death rate as reported by village headmen.

(*F*) *Incidence of diarrhœa and dysentery.*

The incidence, etc., of diarrhœa and dysentery in all headworks camps is as follows :—

Diarrhœa and dysentery.

Year.	Outdoor.	Indoor or clinical dysentery.	Deaths.	Death rate.	DEATH RATE FOR THE DISTRICT.*	
					Reported crude rate.	Verified by medical agencies.
1925 ..	470	21	4	1·6	0·21	2·46
1926 ..	809	16	10	4·4	0·24	6·44
1927 ..	948	46	4	0·9	0·27	2·7
1928 ..	1,129	55	32	6·4	Not available.	
1929 (up to June).	234	6	4	1·9	Not available.	

* *Note.*—The death rate for the Province is based on the usual reporting agency in the villages and is known to be extremely erroneous. The calculated death rate based on verified data supplied by professional agencies exceeds that reported in the usual manner by 12 times in the case of dysentery and 20 to 24 times in the case of pneumonia (1924 to 1928 Provincial statistics).

The outdoor attendance for diarrhœa was high from January to March and again in May. This was to great extent due to the consumption of raw fruit, sugar-cane and melons. Cases passing blood or mucus were admitted, and of these approximately 70 per cent were clinically bacillary dysentery and 30 per cent clinically amœbic dysentery.

The figures include the data from the hospital and all travelling dispensaries.

XVIII. ECONOMIC LOSS DUE TO MALARIA.

The economic loss of malaria is hard to estimate owing chiefly to the contractors' system of recruiting and controlling labour. These men were mainly recruited from the south of the Province, given an advance of pay to support their families in their absence and brought by the contractor to the works.

A common incident at almost any time soon after March, was the number of labourers who reported sick without obvious cause, or more especially who were found in the huts not sick. These men remaining off work and daily demanding to be sent back to their villages once the season for reaping their village crops had set in. Discontent amongst the labour always took the form of pleas of sickness to get their accounts settled by contractors.

It is therefore useless basing any remarks on the figures dealing with labour working under Indian contractors.

PHOTOGRAPH 7

Photographed by M. M. Beg, Lucknow.

The Barrage across the Sarda

One European firm imported their labour direct from Bombay, and these men were all on a higher rate of wages than other labourers, and were a more disciplined and educated class. The following figures are therefore interesting :—

1927-28.

Month.			Possible man hours.	Sick man hours all causes.	Per cent loss man hours.
October	1927	..	3,190	55	1·72
November	"	..	7,828	1,493	19·2
December	"	..	15,601	1,701	10·8
January	1928	..	14,208	1,057	7·44
February	"	..	21,591	1,697	7·8
March	"	..	29,021	1,610	5·5
April	"	..	22,295	1,769	7·4
May	"	..	18,640	4,375	23·4
June	"	..	8,890	1,540	17·2

The rise in May 1928 was phenomenal, owing to exceptional weather conditions. The two rises shown in the above figures run parallel to the Provincial spring and autumn malaria rises but at a very much lower level. The average sickness figures for all causes for the months of 1927 and 1928 are 12·20 and 10·50 per cent respectively. Even assuming that malaria was the only cause of sickness, which is far from correct, these figures show the excellent results of the anti-malarial measures at Banbassa and suggest, as this is admittedly one of the worst malarious zones in India, that the rates for contract work should only be about 10 to 12 per cent above the normal, if anti-malaria operations are carried out.

The following note communicated to the Legislative Council by Sir B. Darley, *Kt.*, Chief Engineer of the construction work, gives his opinion on the value of the anti-malarial measures carried out :—

Note on the value of anti-malarial works at Banbassa.

'It is very difficult to estimate the economic value of the malaria staff at Banbassa in rupees, annas and pies. The work that has been done has certainly enabled the working season to be extended from 15th April to say 15th June, i.e., 2 months each year or 10 months in five years ; in other words the work will thus be able to dispense with the services of about half the divisional staff a year earlier, a saving of probably Rs. 50,000.

'If, however, we take into account the value of delivering water one year earlier for irrigation, the monetary value of the anti-malarial work would probably run to half a crore of rupees.

'Secondly by keeping the labour fit it has been possible to inspire confidence, and good contractors have come forward to take up the work at lower rates than was deemed possible at first.

'I have gone over the estimate and putting this saving at Re. 1 to Rs. 2 per 100 cubic feet of masonry, etc., this saving might be fairly estimated at Rs. 1,50,000—that is of course assuming that any contractors would have taken up the work at all under the adverse circumstances obtaining before the malarial staff got to work. Indeed, it is very doubtful if the Sarda canal head could have been built at all without the expert help we have received from the medical department.'

XIX. Conclusion.

In conclusion I desire to acknowledge the assistance and help received on very many occasions from the Chief Engineer, Sir B. Darley, and the Superintending Engineer, Mr. F. Anderson, C.I.E., and to put on record my appreciation of the work of my Assistant Malaria Officers, Dr. A. C. Banerjea, Dr. B. M. Roy and Dr. P. N. Chatterji; the value of their labours in most trying circumstances cannot be over-estimated.

Appendix I.

The foregoing report embodies the investigations and anti-malarial measures carried out in the Sarda canal zone by the following officers of the Public Health Department, United Provinces, during the years 1920 to 1929:—

Year.	Officers in charge.		Assistant Malaria Officers.	
	Name.	Period.	Name.	Period.
1920	Dr. A. N. Mukerji ..	21- 3-1920 to 17- 4-1920	Dr. A. N. Mukerji ..	8-12-1920 to 31-12-1920
	Lt.-Col. W. A. Mearns, I.M.S.	29-11-1920 to 31-12-1920	Dr. G. D. Ghosh ..	8-12-1920 to 31-12-1920
1921	Lt.-Col. W. A. Mearns, I.M.S.	1- 1-1921 to 24- 2-1921	Dr. A. N. Mukerji ..	1- 1-1921 to 31-12-1921
	Lt.-Col. C. L. Dunn, I.M.S. ..	25- 2-1921 to 3- 3-1921	Dr. G. D. Ghosh ..	1- 1-1921 to 31-12-1921
	Lt.-Col. C. A. Cameron, I.M.S.	4- 3-1921 to 15- 5-1921	....	..
	Lt.-Col. J. A. S. Phillips, I.M.S.	16- 5-1921 to 31-12-1921	....	..

PHOTOGRAPH 8.

Photographed by M M Beg, Lucknou

The Headworks Weir

APPENDIX I—*contd.*

Year.	Officers in charge.		Assistant Malaria Officers.	
	Name.	Period.	Name.	Period.
1922 and 1923	Lt.-Col. J. A. S. Phillips, I.M.S.	1- 1-1922 to 31-12-1923	Dr. A. N. Mukerji ..	1- 1-1922 to 30- 6-1922
	....	..	Dr. G. D. Ghosh ..	1- 1-1922 to 16-10-1922
	....	..	Dr. A. C. Banerjea ..	1- 7-1922 to 31-12-1923
1924	Lt.-Col. J. A. S. Phillips, I.M.S.	1- 1-1924 to 30- 4-1924	Dr. A. C. Banerjea ..	1- 1-1924 to 31-12-1924
	Lt.-Col. C. L. Dunn, I.M.S. ..	1- 5-1924 to 3-10-1924	Dr. B. M. Roy ..	12- 3-1924 to 31-12-1924
	Lt.-Col. J. A. S. Phillips, I.M.S.	4-10-1924 to 31-12-1924	....	..
1925	Lt.-Col. J. A. S. Phillips, I.M.S.	1- 1-1925 to 6- 5-1925	Dr. A. C. Banerjea ..	1- [illegible]-1925 to 31-12-1925
	Lt.-Col. C. L. Dunn, I.M.S. ..	7- 5-1925 to 22- 6-1925	Dr. B. M. Roy	
1925	Lt.-Col. J. A. S. Phillips, I.M.S.	23- 6-1925 to 31-12-1925	....	..
1926	Lt.-Col. J. A. S. Phillips, I.M.S.	1- 1-1926 to 8- 4-1926	Dr. A. C. Banerjea ..	1- 1-1926 to 25- 7-1926
	Lt.-Col. W. A. Mearns, I.M.S.	9- 4-1926 to 4-10-1926	Dr. B. M. Roy .. .	1- 1-1926 to 31-12-1926
	Major D. Clyde, I.M.S. ..	5-10-1926 to 31-12-1926	Dr. P. N. Chatterji .	26- 7-1926 to 31-12-1926
1927	Major D. Clyde, I.M.S. ..	1- 1-1927 to 31-12-1927	Dr. B. M. Roy	1- 1-1927 to 31-12-1927
	....	..	Dr. P. N. Chatterji ..	1- 1-1927 to 31-12-1927

APPENDIX I—*concld.*

Year.	Officers in charge.		Assistant Malaria Officers.	
	Name.	Period.	Name.	Period.
1928	Major D. Clyde, I.M.S. ..	1- 1-1928 to 31-12-1928	Dr. B. M. Roy	1- 1-1928 to 31-12-1928
	....	..	Dr. P. N. Chatterji ..	1- 1-1928 to 31-12-1928
	....	..	Dr. A. C. Banerjea ..	4-10-1928 to 31-12-1928
1929	Major D. Clyde, I.M.S. ..	1- 1-1929 to date.	Dr. A. C. Banerjea ..	1- 1-1929 to date.
	....	..	Dr. B. M. Roy	1- 1-1929 to date.
	....	..	Dr. P. N. Chatterji ..	1- 1-1929 to date.

APPENDIX II.

The food of the labourers.

The staple articles of diet of the labourers from the plains consisted of wheat 'atta' (coarse flour) and 'dal' (lentils), the 'atta' being eaten as unleavened cakes ('chapatties') with the boiled 'dal.' Two meals were consumed daily, one in the morning before going out to work and the other before bed time. For 'atta,' rice was often substituted in the morning or evening meal. In some instances goats' meat or fish was consumed, when available and purchasable, while the 'vegetables' available consisted of onions, spinaches ('methi-ka-sag,' 'loki,' 'palak-ka-sag') and potatoes, all these being invariably fried in mustard oil. The diet of the hill men usually consisted of about 8 ozs. of rice and 2 ozs. of 'dal' in the morning and from ½ to 1 lb. of 'atta' taken as 'chapatties' and 2 ozs. of vegetables in the evening. The daily caloric value was very low. The minimum daily wages of hill men who were poor workers was 6 annas, while imported labourers earned from 10 annas to Re. 1 per day on piece work and, as most of the work was executed on piece work, the unskilled labourers mostly earned a minimum of 12 annas a day without difficulty. Many of the families appeared better off than the average villager, and in many cases whole families were employed on the works and the combined income was large. The factor which was, however, common to all was the relative difficulty of obtaining sufficient supplies of milk and milk products, and of vegetables and potatoes at a reasonable cost. The actual prices which prevailed were on the

average slightly high, owing to the cost of carriage being added to the rates prevailing in other towns.

Certain food supplies were brought into camp by the villagers from the villages of Sarda Got, Salani Got, Maniari Got, and Tharuhat Got. These consisted mainly of vegetables such as 'palak-ka-sag,' 'methi-ka-sag' and 'loki,' of milk, 'dahi' (curd), small numbers of eggs and fowls and small quantities of 'atta' and rice, the prices charged for these being considerably less than the bazaar prices prevailing in the labourers' camps.

Two bazaars were maintained, one near the workshops on the cliff and the other in the main labour camp. The workshop bazaar ultimately degenerated in 1927, as the bulk of the labour bought their goods from the shops in the main labour camp. The prices in the bazaar were not controlled and competition between shopkeepers was at times keen.

The following are examples of the typical diets of the labourers from the plains.

(1) *Diet in general use.*

Food-stuffs	Quantity.	Proteins in grammes.	Fats in grammes.	Carbo-hydrates in grammes.	Total calories.	Vitamins.			
						A	B	C	D
'Atta' ..	8 ozs.	31·20	4·32	162·80	816	+	++	0	..
'Dal' ..	4 „	26·00	4·00	64·00	400	+	++	0	..
Mustard oil ..	½ oz.	..	14·00		126	0	0	0	..
Onions ..	1 „	0·37	0·03	3·06	14	V. L.	++	+	..
Salt	..	..	..	..	..	..	..	..	..
'Atta' ..	8 ozs.	31·20	4·32	162·80	816	+	++	0	..
Potatoes ..	8 „	5·60	0·32	65·20	288	+	++	0	..
Onions ..	1 oz.	0·37	0·03	3·06	14	V. L.	++	+	..
'Methi, Palak or Loki' } 'sag'	2 ozs. (approximately).	0·60	0·30	4·50	15	Nil as cooked.			
Mustard oil ..	½ oz.	..	14·00	..	126	0	0	0	..
Salt	..	..	..	..	..	..	..	..	..
Total		95·34	41·32	465·42	2,615	..	..	..	..
Less 10 per cent for waste		85·80	37·18	418·87	2,353·5	..	..	..	..

V. L. = very low.

(2) The first variation in this diet was that instead of vegetables and potatoes in the evening meal 'dal' 4 ozs. was often substituted. This gives a food value to the daily diet of :—

	Proteins in grammes.	Fats in grammes.	Carbo-hydrates in grammes.	Total calories.
	114·77	30·67	456·66	2,572
Less 10 per cent for waste.	103·29	27·60	410·99	2,314·80

(3) The second common variation was to substitute parboiled rice 8 ozs. for the bulk of the 'atta' in the morning meal. Approximately 2 ozs. of 'atta' were then consumed in the form of 'chapatties' This gives a food value to this diet of :—

	Proteins in grammes.	Fats in grammes.	Carbo-hydrates in grammes.	Total calories.
	86·76	39·84	553·2	2,919 1
Less 10 per cent for waste.	78 08	35·86	497 88	2,427 1

(4) The third variation was that goat's meat, 8 ozs., was very occasionally substituted for the potatoes, oil and vegetables in the evening meal, the diet thus having a value of :—

	Proteins in grammes.	Fats in grammes.	Carbo-hydrates in grammes.	Total calories
	146·37	32·67	392·66	2,460
Less 10 per cent for waste.	131·73	29·40	353·39	2,214

The first obvious defect of these diets is the unsuitability of the proteins, a fault common to all Hindu dietaries except where milk, 'dahi' (curd), and green vegetables are consumed in sufficient quantities. The percentage of labourers able to obtain and pay for milk or 'dahi' in such quantities as to affect the diet was, however, very small indeed, and though the amount of the protein is up to the standard necessary, its 'unsuitability' is a known cause of low powers of endurance

and incapacity to resist disease. Again, this protein requires very high ratios of green vegetables, fruit, etc., and is all derived from vegetable sources.

The 37·18 grammes of fat provided in the diet is 100 per cent below the usual requirements and the carbohydrates not high enough to offset this. None of the fat is from animal sources. The effect of this on coolies performing exhausting work in a tropical climate is obvious ; œdema of the legs, susceptibility to disease and delayed convalescence after malaria and bowel infections were commonly met with.

The carbohydrates are within normal limits, though mostly derived from ' atta ' and ' dal.' The total caloric value is very low, especially when the work which these men were called upon to do is taken into consideration.

As wheat ' atta ' is the main ingredient of the diet, although it is a rich source of vitamin B, the absence of adequate milk, ghee or ' dahi,' green vegetables and animal fat to provide vitamins A, B, C and D and calcium and sodium in sufficient quantities, becomes serious. The vegetables are fried in the mustard oil; no vitamin content can be attributed to them, and in addition to this the quantity should be at least 4 times as great by weight as the daily ' dal ' intake.

In the second dietary the substitution of ' dal ' for the vegetables means the cutting out of the mustard oil, thus lowering the fat value, in addition to lowering the carbohydrates and total calories still further. The quantity of ' dal ' in this diet is too high, the maximum daily intake assimilable being put by McCarrison at 4 to 5 ounces.

The third dietary is extremely low in proteins ; the fat value is low but is offset to some extent by the relatively high carbohydrates ; the total calories are still very low.

In the fourth diet the protein is too high and the other values too low. The fourth diet has the advantage of the protein and fats being derived to some extent from animal sources.

No. 1 diet is the usual routine diet and is mainly modified by increasing the quantity of ' chapatties ' eaten.

Perhaps the chief defect of these dietaries is the low vitamin content. That vitamin A was deficient was obvious, especially from the number of the cases of inflammatory eye conditions, bowel diseases, ' colds ' and several cases of night blindness. Vitamin B is fairly well represented in the diet. Vitamin C is very low indeed in the cooked diet, but is made up to some small extent by the taking of raw milk and ' dahi,' and perhaps to a greater extent by the eating of fruit in their seasons, such as melons, oranges, limes. mangoes, and especially by the universal habit of chewing raw sugar-cane when in season. Many scurvy cases were seen in adults during the construction work—most of these with early signs of the disease—while the condition was relatively common in children.

Vitamin D is non-existent in the diets, but this is immaterial as the labourers worked all day almost naked under a tropical sun. The practice of rubbing oil on the body was common with many of the castes represented.

The above criticisms of the various dietaries must not be taken to infer that any fault existed in the official arrangements, but rather that the Indian labourer habitually consumes a diet which is defective in many respects and that even at a time when he is relatively better off than when living in his village. The 'banias' invariably import the food for which there is a demand and had vegetables and 'ghee' been in great demand, larger quantities would certainly have been imported.

Appendix III.

Statement showing the number of cases treated by the travelling dispensaries in the various labour aggregations.

Number of travelling dispensary.	Working season.	Total of all diseases.	Malaria.	Diarrhœa and dysentery.	Pneumonia.
P. H. T. D. No. 31 ..	1924–25	4,318	1,743	88	6
	1925–26	4,591	1,831	271	5
	1926–27	6,403	2,402	236	4
	1927–28	9,265	1,886	200	11
P. H. T. D. No. 32 ..	1924–25	3,322	1,394	36	2
	1925–26	9,152	1,823	59	12
	1926–27	8,071	2,165	212	87
	1927–28	4,998	1,366	261	16
P. H. T. D. No. 33 ..	1924–25	3,148	829	43	3
	1925–26	3,620	1,056	53	12
	1926–27	3,298	1,169	84	2
	1927–28	3,813	1,366	43	2
P. H. T. D. No. 34 ..	1924–25	4,714	1,300	117	6
	1925–26	6,725	1,717	144	12
	1926–27	7,265	1,975	157	7
	1927–28	7,677	2,047	158	11
P. H. T. D. No. 35 ..	1924–25	1,024	334	12	2
	1925–26	5,213	1,966	73	..
	1926–27	3,566	1,531	15	3
	1927–28	3,120	637	43	6
P. H. T. D. No. 36 ..	1924–25	3,609	1,207	130	1
	1925–26	7,482	2,345	58	1
	1926–27	4,501	1,385	39	6
	1927–28	8,866	3,010	146	4
Total ..	..	127,661	38,484	2,678	221

The figures for the months on which these dispensaries were in the headworks area have been added in Graph VI.

APPENDIX IV.

Incidence of pneumonia by months, January 1925 *to June* 1929.

Year.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.	Population.	Total cases.
1925 ..	3,037	29	3,401	25	2,999	18	2,264	27	2,148	20	..	..	..	..	..	..	..	..	1,131	4	2,716	21	4,156	46
1926 ..	3,897	34	3,433	73	2,782	71	2,117	22	2,706	31	658	3	120	..	..	..	..	..	510	1	1,011	4	3,631	15
1927 ..	5,823	10	5,708	11	4,196	12	3,622	15	3,005	10	904	3	113	2	..	..	..	..	473	2	2,101	9	6,536	11
1928 ..	9,486	45	9,380	22	7,123	25	6,550	14	4,710	26	1,956	14	761	1	..	..	..	..	1,114	3	1,688	4	3,760	9
1929 (up to June).	3,660	14	2,681	22	2,319	15	2,023	6	2,332	2	879	2	..	..	..	..	..	..	..	..	..	..	..	..
TOTAL ..	25,903	132	24,603	153	19,419	141	16,576	84	14,901	89	4,397	22	994	3	..	..	..	..	3,228	10	7,516	38	18,083	81
Incidence rate per mille.	5·09		6·21		7·26		5·00		5·97		5·00		3·01		..		..		3·09		5·05		4·47	

Appendix V.

Statement showing the expenditure for medical relief per season for the period 1920–29.

Particulars.	1920–21.	1921–22.	1922–23.	1923–24.	1924–25.	1925–26.	1926–27.	1927–28.	1928–29.	1929–30 (April to June).
	Rs. As. P.	Rs. As. P.	Rs. As. P.	Rs. As. P.	Rs As P.	Rs As. P.	Rs. As P.	Rs. As. P.	Rs. As. P.	Rs. As. P.
Pay of the hospital staff	2,358 0 0	4,679 0 0	8,200 0 0	8,200 0 0	8,200 0 0	8,200 0 0	8,200 0 0	8,200 0 0	8,211 0 0	2,050 0 0
Cost of quinine ..	685 12 0	798 0 0	865 0 0	1,023 0 0	1,880 12 0	1,379 10 0	2,307 1 0	1,941 0 0	3,007 8 0	1,900 0 0
Cost of cinchona ..	..	..	..	215 5 0	495 6 0	147 13 0	81 0 0	450 0 0	450 0 0	..
Assistant surgeon and compounders' quarters.	..	..	3,119 2 6	..	..	..	..	..	..	..
Quarters for the medical staff.	..	..	5,378 0 1	..	..	..	..	..	..	..
Cost of dispensary building.	..	..	4,277 4 6	..	..	..	..	..	..	..
Cost of infectious diseases huts (temporary).	..	..	..	..	..	124 0 0	510 0 0	1,464 0 0	..	..
Total drug and hospital accessories excluding cost of quinine and cinchona.	1,089 1 2	4,209 14 6	4,628 1 0	5,274 0 6	1,400 13 3	1,604 13 3	2,521 6 0	1,643 15 6	1,063 3 0	267 3 9
Grand total for each year	4,132 13 2	9,686 14 6	26,467 8 1	14,712 5 6	11,976 15 3	11,456 4 3	13,619 7 0	12,234 15 6	14,195 11 0	4,217 3 9

Note.—The variation in the expenditure in quinine is mainly due to the carrying over or otherwise of stocks from one working season to another from 1926 onward.

APPENDIX VI.

Expenditure per working season.

Heading.	1921–22.	1922–23.	1923–24.	1924–25.	1925–26.	1926–27.	1927–28.	1928–29.	1929–30 (April to June).	REMARKS.
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
(1) Pay of sanitary staff.	2,827	2,105	5,631	6,003	5,787	5,232	6,752	4,950	922	Does not include superior personnel.
(2) Expenditure on account of anti-malaria gang and material (oil, etc.).	9,934	7,438	8,845	5,829	5,867	3,347	1,847	2,563	133	Does not include pay of coolies on anti-malaria work carried out by contract.
(3) Maintenance charges on water supply system (initial cost Rs. 97,398).	..	2,067	4,736	4,200	4,230	3,224	3,401	2,654	..	

Appendix VII.

The annual average cost of running a travelling dispensary is as follows :—

Particulars.	Amount. Rs.	A.	P.
Pay and travelling allowance of medical officer and staff at Rs. 176-13 per mensem.	2,122	0	0
Cost of drugs and instruments, etc., at Rs. 430 per annum.	430	0	0
Contingencies at Rs. 24-6 per mensem ..	292	8	0
Total cost ..	2,844	8	0

Appendix VIII.

Period.	Daily labour strength.	Number of men quinınized	Percentage attendance.	Remarks.
Spring of 1924—Benign tertian season.				
Week ending—				
10-5-24 ..	1,215	585	48	
17-5-24 ..	1,294	285	22	
24-5-24 ..	1,381	205	14	
7-6-24 ..	1,108	478	34	10 grains quinine in solution on two consecutive days weekly.
14-6-24 ..	597	344	58	
21-6-24 ..	528	192	36	
28-6-24 ..	265	48	18	
Spring of 1925—Benign tertian season.				
21-3-25 ..	2,552	125	5	
4-4-25 ..	2,259	12	·5	
18-4-25 ..	2,239	39	2	
2-5-25 ..	2,184	105	5	
16-5-25 ..	2,120	89	4	Do.
23-5-25 ..	1,753	1,145	65	
30-5-25 ..	2,285	848	37	
13-6-25 ..	596	94	16	
20-6-25 ..	338	108	32	

APPENDIX VIII—*contd.*

Period.	Daily labour strength.	Number of men quininized.	Percentage attendance.	REMARKS.
		Spring of 1926—Benign tertian season.		
Week ending—				
27–3–26 ..	2,385	75	3	10 grains quinine in solution on two consecutive days weekly.
3–4–26 ..	2,281	15	·6	
10–4–26 ..	1,990	5	·2	
17–4–26 ..	1,944	50	3	
24–4–26 ..	2,253	16	·7	
1–5–26 ..	2,734	1,026	37	
8–5–26 ..	2,804	1,384	49	
15–5–26 ..	2,874	1,270	44	
22–5–26 ..	2,743	1,297	47	
29–5–26 ..	2,379	1,165	49	
5–6–26 ..	1,472	639	43	
12–6–26 ..	686	330	48	
19–6–26 ..	369	127	34	
26–6–26 ..	112	37	33	
		Spring of 1927—Benign tertian season.		
2–4–27 ..	3,580	68	2	12 grains cinchona febrifuge pills each on two consecutive evenings per week.
9–4–27 ..	3,628	110	3	
16–4–27 ..	3,619	80	2	
23–4–27 ..	3,615	5	·1	
30–4–27 ..	3,668	45	1	
7–5–27 ..	3,408	1,184	35	
14–5–27 ..	2,856	1,450	51	
21–5–27 ..	2,811	1,386	49	
28–5–27 ..	2,647	893	34	
4–6–27 ..	1,850	705	38	28-5-27. Week of treatment with 10 grains cinchona febrifuge daily commenced.
11–6–27 ..	868	696	80	
18–6–27 ..	489	489	100	

Works closed on 25-6-27. From 100 to 160 labourers permanently remained on the works during the rains.

APPENDIX VIII—*contd.*

Period.	Daily labour strength.	Number of men quininized.	Percentage attendance.	REMARKS.
		Spring of 1928—Benign tertian season.		
Week ending—				
21-4-28 ..	6,776	2,382	35	Cinchona febrifuge 12 grains in pills on two consecutive days per week.
28-4-28 ..	5,373	5,100	95	
5-5-28 ..	5,394	4,542	84	
12-5-28 ..	4,856	3,091	64	
19-5-28 ..	4,685	2,114	45	
26-5-28 ..	3,907	3,361	86	
2-6-28 ..	3,153	3,150	100	At end of season one week's 'treatment' given in cinchona febrifuge. Work closed 23-6-28; 900 men remained till the middle of July and 200 in August and 400 in September.
9-6-28 ..	2,783	1,618	58	
16-6-28 ..	2,526	681	27	
23-6-28 ..	1,056	265	26	
		Spring of 1929—Benign tertian season.		
13-4-29 ..	1,951	1,951	100	
20-4-29 ..	1,843	1,763	96	
27-4-29 ..	2,032	2,032	100	
4-5-29 ..	2,740	1,278	47	
11-5-29 ..	2,504	1,996	80	Cinchona febrifuge pills grs. 12 on two consecutive days per week.
18-5-29 ..	2,280	1,448	63	
25-5-29 ..	1,803	1,086	60	
1-6-29 ..	1,647	980	59	
8-6-29 ..	1,066	744	70	One week's treatment made available at end of season.
15-6-29 ..	763	579	76	

APPENDIX VIII—*contd.*

Period.	Daily labour strength.	Number of men quinnized.	Percentage attendance.	REMARKS.
	Autumn of 1924—Subtertian season.			
Week ending—				
8-11-24 ..	699	699	100	
15-11-24 ..	816	816	100	
22-11-24 ..	1,421	1,421	100	
29-11-24 ..	1,619	1,199	74	
6-12-24 ..	2,065	1,208	58	Quinine sulphate grains 10 in solution on two consecutive nights per week.
13-12-24 ..	2,455	1,434	54	
20-12-24 ..	2,820	116	4	
27-12-24 ..	2,998	98	3	
17- 1-25 ..	3,038	59	2	
24- 1-25 ..	3,000	164	5	
7- 2-25 ..	2,929	20	·7	
14- 2-25 ..	3,908	87	2	
21- 2-25 ..	3,380	33	·6	
28- 2-25 ..	3,384	205	6	
	Autumn of 1925—Subtertian season.			
31-10-25 ..	1,131	346	20	
7-11-25 ..	1,976	766	39	
14-11-25 ..	2,381	1,343	56	
21-11-25 ..	3,128	931	30	
28-11-25 ..	3,379	1,313	38	
5-12-25 ..	3,785	1,835	48	Quinine sulphate grains 10 in solution on two consecutive nights per week.
12-12-25 ..	4,324	2,993	69	
19-12-25 ..	4,266	1,890	44	
26-12-25 ..	4,241	40	·9	
2- 1-26 ..	4,161	80	2	
9- 1-26 ..	4,055	72	2	
16- 1-26 ..	3,971	38	1	
23- 1-26 ..	3,761	146	4	
30- 1-26 ..	3,540	130	4	
6- 2-26 ..	3,386	16	·5	
13- 2-26 ..	3,373	59	2	
20- 2-26 ..	3,480	18	·5	
27- 2-26 ..	3,494	25	·7	

Appendix VIII—*contd.*

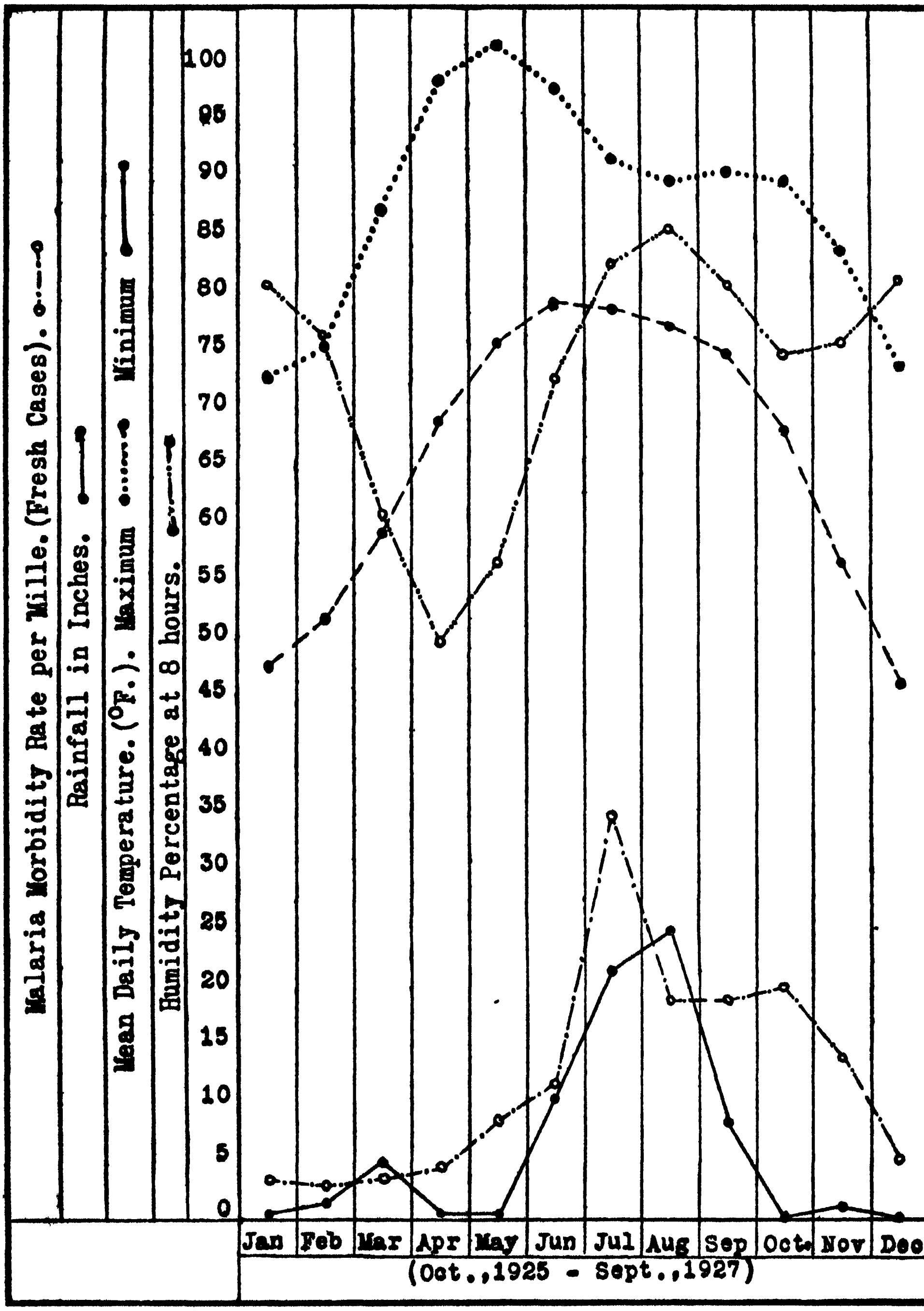
Period.	Daily labour strength.	Number of men quininized.	Percentage attendance.	Remarks.
		Autumn of 1926—Subtertian season.		
Week ending—				
6-11-26 ..	561	558	98	Quinine sulphate grains 10 in solution or pill as desired on two consecutive nights per week.
13-11-26 ..	829	820	100	
20-11-26 ..	1,474	1,179	80	
27-11-26 ..	1,182	1,182	100	
4-12-26 ..	2,466	2,450	99	
11-12-26 ..	3,297	2,638	80	One week's treatment 10 grains daily given. Subsequent daily distribution of quinine on works in day-time are counted as hospital treatment doses issued and not shown here.
		Autumn of 1927—Subtertian season.		
15-10-27 ..	614	84	14	Quinine sulphate grains 10 in solution or pill as desired on two consecutive nights per week. One week's daily treatment made available at end of season.
22-10-27 ..	683	676	98	
29-10-27 ..	667	664	100	
5-11-27 ..	1,405	676	48	
12-11-27 ..	1,679	853	51	
19-11-27 ..	2,082	1,059	51	
26-11-27 ..	3,040	1,566	51	
3-12-27 ..	3,420	1,854	54	
10-12-27 ..	4,727	3,848	81	
17-12-27 ..	7,014	4,723	67	

Appendix VIII—*concld.*

Period.	Daily labour strength.	Number of men quininized.	Percentage attendance.	Remarks.
Autumn of 1928—*Subtertian season.*				
Week ending—				
20-10-28 ..	1,395	406	29	Evening distribution on return from works.
27-10-28 ..	1,397	858	61	
3-11-28 ..	762	760	100	
10-11-28 ..	861	858	98	
17-11-28 ..	1,161	719	62	
24-11-28 ..	2,212	988	45	One week's daily treatment made available at end of season.
1-12-28 ..	3,094	1,188	38	
8-12-28 ..	3,851	1,840	48	
15-12-28 ..	4,112	1,409	34	
22-12-28 ..	3,910	1,408	36	
29-12-28 ..	3,833	1,297	34	Distribution on works in daytime.
5- 1-29 ..	4,755	2,358	50	
12- 1-29 ..	5,024	2,253	45	
19- 1-29 ..	3,053	2,246	73	
26- 1-29 ..	2,744	2,318	84	
2- 2-29 ..	2,790	2,191	78	

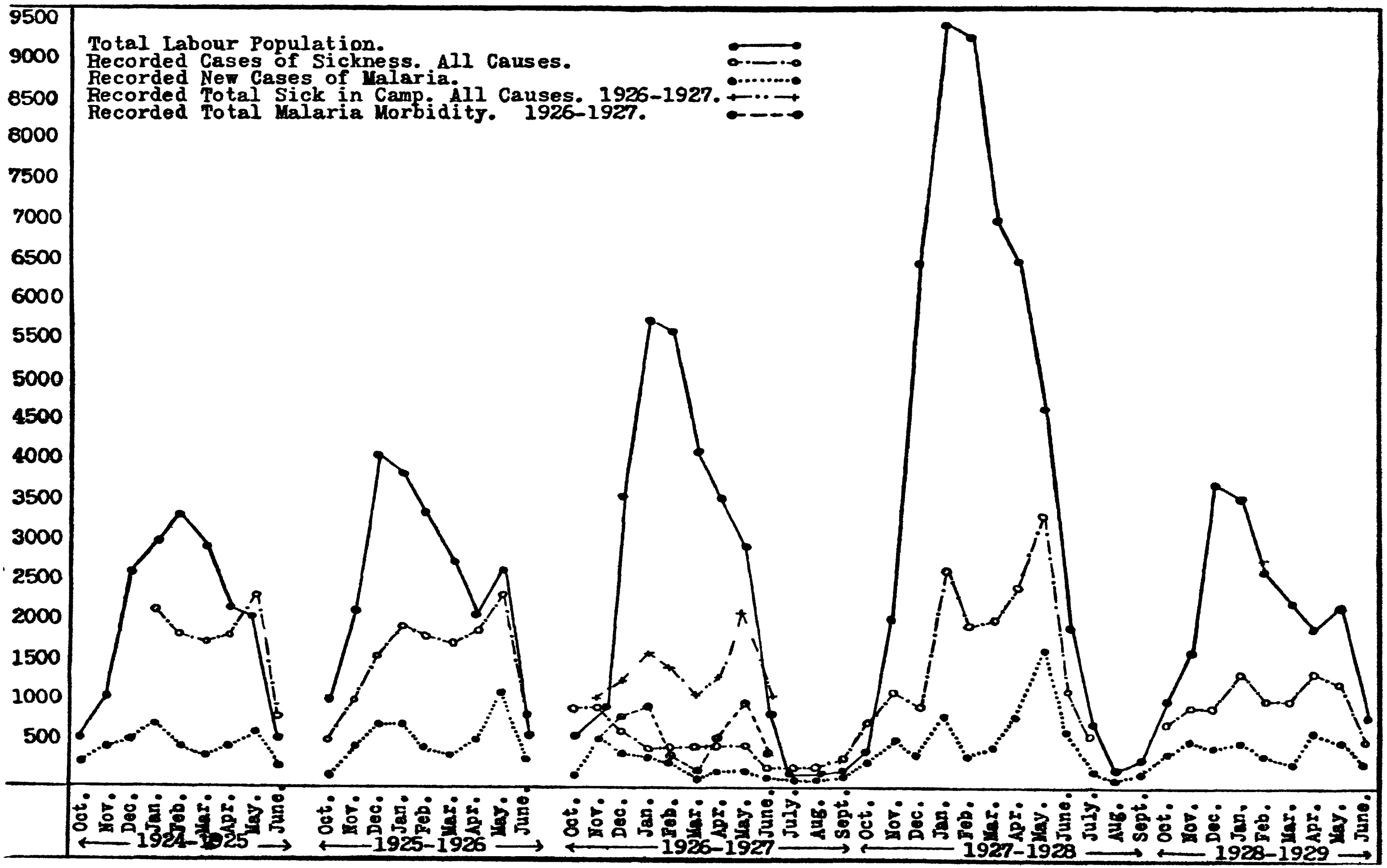
GRAPH IV.

The relationship between meteorological factors and the incidence of malaria.



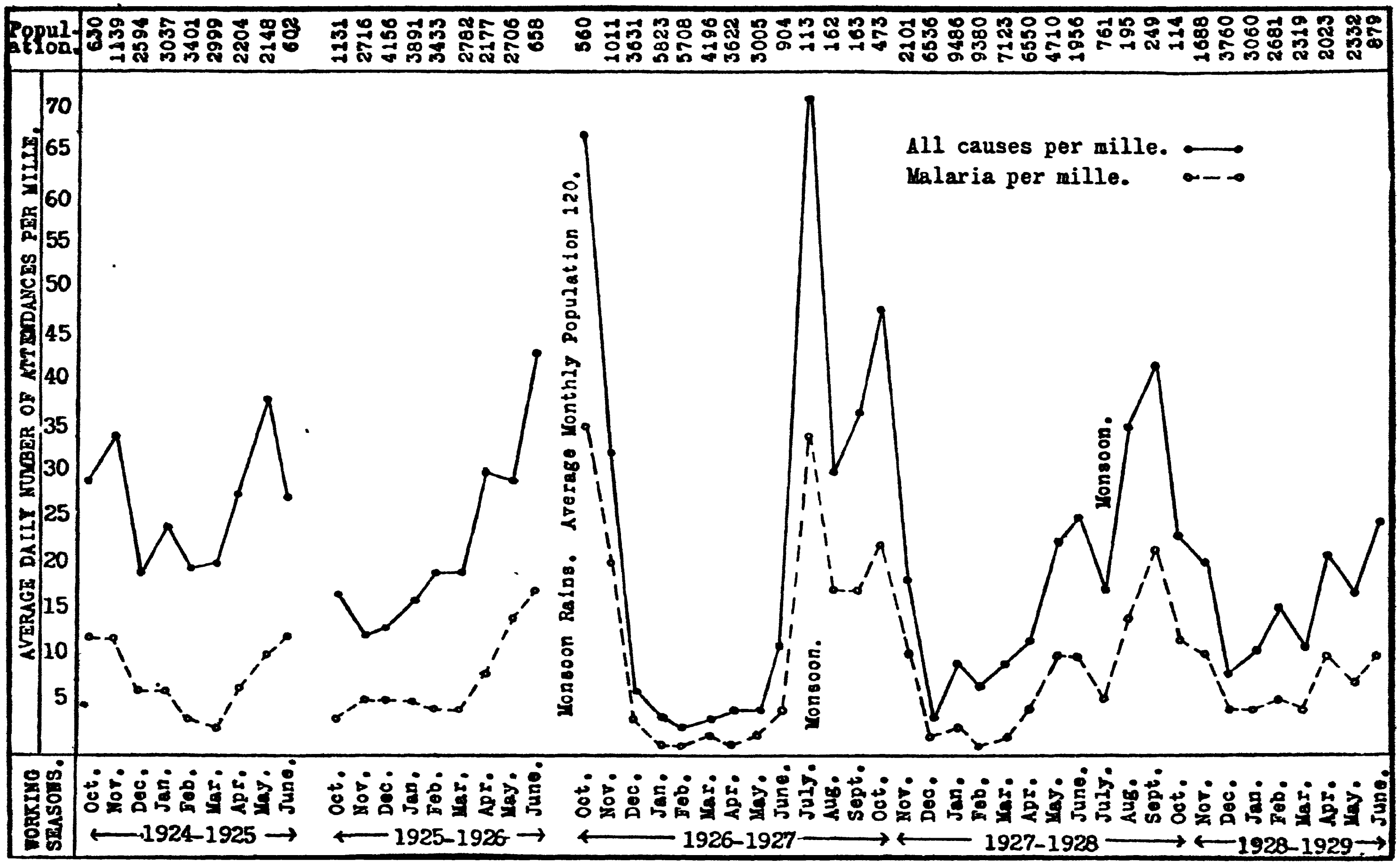
GRAPH V.

The average daily labour strength and the total recorded sick cases per month, 1924–1929.



GRAPH VI.

Average daily attendances for all causes and for malaria per mille population.



Records of the Malaria Survey of India, Vol. II, No. 1, March, 1931.

REPORT ON A MALARIA SURVEY OF THE TEA GARDENS IN THE MARIANI MEDICAL ASSOCIATION, ASSAM.

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[December 23rd, 1930.]

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Part I.

Part II.

NOTES ON INDIVIDUAL GARDENS.

PART I.

INTRODUCTION.

THE Mariani Medical Association has charge of a group of seven Tea Companies, controlling eighteen gardens, which, though otherwise distinct, are grouped together for medical purposes. The gardens lie in the Sibsagar District of Assam some ten to twenty miles to the south of Jorhat, near the foot of the Naga Hills and some three hundred and fifty feet above sea-level.

The chief meteorological data recorded in the nearest Meteorological Station, Sibsagar, are shown in Table I. The humidity is very high throughout the year and the rainfall occurs chiefly between March and October, the total for the year being 96 inches. There are definite cold and warm seasons, the latter lasting from April to October, during the whole of which the transmission of malaria is possible.

TABLE I.

Showing the normal temperature, humidity and rainfall records in Sibsagar, Assam.

Month.	Temperature. Mean maximum. °F.	Temperature. Mean minimum. °F.	Relative Humidity mean 8 A.M.	Rainfall total.
January	70·0	49·7	98	1·29 inches.
February	72·6	53·3	96	2·01 ,,
March	78·6	59·8	91	4·78 ,,
April	81·2	65·9	90	10·11 ,,
May	85·4	71·5	90	11·89 ,,
June	88·7	76·1	91	14 21 ,,
July	89·2	77·7	92	17·01 ,,
August	88·6	77·6	93	16·27 ,,
September	87·6	76·2	93	11·70 ,,
October	84·1	70·6	95	5·10 ,,
November	77·7	59·6	96	1·10 ,,
December	71·1	50·6	96	0·52 ,,

Rainfall records are maintained on all the gardens in the Association ; in Mariani the average rainfall for the last thirty years was 82 inches. The rainfall is very variable, the annual total in Mariani varying from 56 to 107 inches, while in any one year there may be variations of as much as thirty inches between different gardens within a few miles of each other.

Through the district in which these gardens lie there passes one large river, the Desoi River, and four smaller rivers, running down from the Naga Hills ; the whole area is intersected by small streams running in tortuous channels. The soil is sandy and porous, rain water collections thus tending to disappear rapidly.

We visited Mariani between the 25th of May and the 5th of July 1930, to make a survey and to report on the amount of malaria present, the species of mosquito transmitting it, and to recommend such anti-malaria measures as seemed advisable. During our stay we received every help, and wish to express our thanks for the hospitality and assistance shown to us, especially by the Medical Officer and the Honorary Secretary of the Mariani Medical Association.

MALARIA.

Amount of malaria present.

As many children as possible were examined from every coolie lines of each garden for enlargement of the spleen, and in a number of cases thick blood films were taken by the method of Sinton (1924) ; the time involved in the examination of blood films made it impossible to take these from all the children seen, but an attempt was made to get a reliable sample from as many gardens as possible.

Out of 1,737 children between the ages of two and ten examined, 991 or 57 per cent had enlarged spleens, the district being thus classed as a hyperendemic area. The spleen rates in different gardens, and even in different lines of the same garden, showed great variations. These ranged from 9 to 93 per cent, and depended on the proximity of the breeding places of dangerous species of anophelines.

Of the 781 children from whom blood films were taken, 356 or 45 per cent had parasites in the peripheral blood. The parasite rates varied from 13 per cent to 69 per cent in agreement with the spleen rates. *P. falciparum* was present in 256 or 72 per cent, *P. vivax* in 73 or 20 per cent, and *P. malariæ* in 17 or 5 per cent, while in 9 or 3 per cent of the cases there was a mixed infection with *P. falciparum* and *P. vivax*.

In addition to these children, 255 adults were examined. These had a spleen rate of 24 per cent and a parasite rate of 22 per cent.

The age distribution of the infections will not be dealt with here as it is complicated by the varying severity of the malaria in the different lines. The course of events in the individual seems to be that the young child passes through a series of serious attacks of malaria comparable to those which are experienced by the newly arrived European. After a number of these attacks a relative immunity is gradually acquired with the result that the frequency of the attacks is much reduced.

The adult who has passed through these stages in childhood has developed a considerable degree of immunity and only shows the clinical symptoms and signs of malaria after his resistance has been reduced or he has been subjected to very frequent inoculation with sporozoites. He recovers from such an attack in a shorter time than would a child or a non-immune adult. He may, however, be debilitated for long periods by chronic infections which do not completely prevent him from working.

The full details of the results of the examination of the bloods and spleen are given in the notes on the individual companies in Part II of this report.

Seasonal incidence of malaria.

A few cases of malaria are seen in the hospitals throughout the cold weather. probably due to relapses; in April or May the numbers rapidly increase, to reach their maximum in either July, August or September, after which they decline to reach their minimum in December.

Unfortunately, in most gardens, accurate statistics of malaria incidence have been kept for the last four years only, and it is therefore difficult to trace the relationship between the rainfall and the severity of the epidemic. It appears, however, that this relationship is not close, as the number of new cases of malaria per annum in Mariani was not found to show any correlation with the total amount of rain.

TABLE II.

Rainfall and malaria at Mariani.

Year.	Rainfall.	New cases of malaria per 1,000 inhabitants.
1926	77·02 inches.	2,061
1927	82·21 „	1,584
1928	92·02 „	2,185
1929	93·75 „	1,553

The nature of the rainfall is said to influence the malaria incidence, continuous slight rain being worse than a series of heavy downpours, such as would tend to wash the larvæ away. In the absence of reliable malaria statistics extending over a number of years it is impossible to confirm this, though such figures as are available appear to show that initial heavy rain delays the annual outbreak of malaria. Thus in Mariani the total rainfall in 1928 and 1929 was almost exactly the same. The heavy rain, however, fell one month earlier in 1929 than in 1928, whilst the malaria curve reached its height two months later in 1929 than in 1928, the actual figures being given in Table III.

TABLE III.

Seasonal incidence of malaria and rainfall in Mariani.

Month.	1928.		1929.	
	Rainfall (inches).	New cases of malaria.	Rainfall (inches).	New cases of malaria.
January ..	0·26	15	1·76	17
February ..	0·84	22	0·24	13
March ..	3·72	34	4·88	12
April ..	5·89	19	9·44	35
May ..	9·00	31	14·62	25
June ..	14·27	69	16·07	35
July ..	15·73	196	21·51	80
August ..	19·11	155	10·26	146
September ..	16·60	111	9·41	172
October ..	5·69	102	4·58	159
November ..	0·91	41	0·00	116
December ..	0·00	25	0·98	38
TOTAL ..	92·02	820	93·75	848

The loss inflicted by malaria.

In the tea gardens there is a shortage of labour, few of the gardens being able to secure sufficient for their needs. The annual occurrence of an epidemic at the time of year when labour is most needed, the plucking season, is a source of direct financial loss to the gardens. The actual loss which is incurred as a result of the absence of a coolie from work during the plucking season can only be calculated by the Garden Manager concerned, and will not be attempted by us.

The loss through sickness due to malaria can be divided under three heads, sickness directly due to malaria, sickness indirectly attributable to malaria, and general debility which does not prevent the labour working, but lowers his efficiency.

Sickness directly due to malaria.

In Table IV the number of sick days lost through malaria is given for those gardens for which the figures are available. The figures given are not actuals, but have been reduced to a ratio per thousand population, to make the figures for each garden comparable with those from other gardens.

TABLE IV.

Malaria morbidity.

Number of sick days lost annually through malaria, per 1,000 population.*

	1926.	1927.	1928.	1929.	Average.
Bandersulia	1,685	856	1,727	1,162	1,357
Keremiah	..	..	2,257	2,570	2,413
Mariani and Hattejuri ..	2,061	1,584	2,185	1,553	1,846
Hunwal	3,015	1,120	1,531	1,687	1,838
Nagadholie	3,673	3,210	2,131	3,735	3,187
Kathalguri	..	..	2,850	1,550†	2,200
Heleaka	..	..	1,517	1,032	1,274
Hattipatti	..	..	735	995	865

* Only gardens on which there is a hospital are included in these figures.

† This figure for Kathalguri for 1929 is for the first ten months of the year only.

From this table it will be seen that there is an average loss of 1,872 days through malaria for every 1,000 persons living on the estate, or about two days per person per year. These figures, of course, include all cases of sickness whether occurring in adult workers or in children but this does not vitiate them because it is the rule for the mother to remain away from work if her child is ill, and in the case of any person being seriously ill one other person absents himself to care for the invalid.

Sickness indirectly attributable to malaria.

Under this heading come those cases of sickness due to malaria but showing abnormal symptoms, such as choleraic or dysenteric manifestations, which are entered under the heading of the symptoms manifested, and cases of other diseases appearing in a population weakened by repeated infection with malaria. The fact that such cases occur and are fairly numerous can be seen from a study of the morbidity returns of any estate. It will be seen from these that the figures for sickness due to 'other causes than malaria' show a seasonal curve very similar to that of malaria, though often reaching its height at a slightly later time of year than the malaria curve, which is readily explained by the greater frequency of abnormal cases and complicating diseases at the end of an epidemic than at its commencement. This is illustrated in Table V which gives the figures for the gardens of the Hunwal Tea Company for the two years 1928 and 1929. The figures for all companies show similar phenomena, but a typical one has been taken as an example.

TABLE V.

New cases seen at hospitals of the Hunwal Tea Company during 1928-29.

Month.	Malaria.	Other causes than malaria.
January ..	105	453
February ..	70	562
March	126	710
April	133	962
May	191	665
June	421	763
July	522	859
August	510	1,052
September ..	440	1,468
October ..	408	1,011
November ..	268	834
December ..	142	592
TOTAL .	3,336	9,931

The figures for 'other causes than malaria' show a marked increase during the malaria season, which we believe cannot be completely explained by the seasonal incidence of any other disease. During the malarious months of June to November there were 2,043 more cases under this heading than in the non-malarious months of December to May, and half of these at least may be safely attributed to malaria; thus the number of cases indirectly attributable to malaria may be put at 1,020 in this series, or 31 per cent of the number of cases directly attributed to malaria.

Loss due to general debility.

In any community subject to malaria there is a certain amount of minor sickness due to malaria which is insufficient to prevent the labourer going to work, and debility following on the attack after he has returned to work, both of which result in lost efficiency. It is impossible to make an estimate of the loss caused by this but the experience of planters in other parts of the world has shown that there is an increase in the amount of work done per day after the successful conclusion of anti-malaria measures. For instance, the United Fruit Company, operating in highly malarious areas in the Gulf of Mexico, found a progressive increase in the amount of cane cut per man per day from one ton to 1·61 tons as the health of the District was improved (Deeks, 1929).

Other forms of loss.

To the amount of time lost through malaria there must be added a part of the hospital expenses; cost of quinine; loss due to sickness among the managerial staff and some share of the cost of recruitment of labour. This last item is added because it is the endeavour of every planter to persuade his coolies to settle permanently on his plantation; an unhealthy garden becomes unpopular amongst the coolies, who leave it, and new labour has to be recruited in their place.

ANOPHELINE MOSQUITOES.

Species present.

Careful searches were made in the vicinity of the lines for anopheline larvæ, all possible types of breeding places being searched, and collections of adult anopheline mosquitoes were made in the majority of lines by means of the traps devised by Strickland and Chowdhury (1930). The following thirteen species were found, all being found both in the adult and larval form, except *A. aitkenii*, of which larvæ only were found:—

A. aconitus.
A. aitkenii.
A. barbirostris.
A. culicifacies.
A. fuliginosus.
A. hyrcanus.
A. kochi.
A. leucosphyrus.
A. maculatus.
A. minimus (*A. funestus* of Strickland and Chowdhury).
A. philippinensis.
A. tesselatus.
A. vagus.

Of these thirteen species, *A. minimus* and *A. culicifacies* are undoubtedly dangerous carriers of malaria, having been repeatedly found infected in nature in India, the former particularly in Assam. *A. maculatus* and *A. aconitus* are possible carriers, having been found infected and incriminated in other parts of the world, but never in Assam, though a considerable number have been dissected. In the area under survey the two latter species may be ignored as important carriers on account of their scarcity at the time when the transmission of malaria was taking place.

Breeding places.

The chief types of breeding places searched are classified below, together with a brief description of the anopheline fauna found in them. Details of the anopheline larvæ found on each estate are given in tabular form in Appendix I.

(1) '*Kutcha*' *drains and nullahs.* In and around every coolie lines there are a number of earth drains carrying off the rain water and waste water from the lines. They generally contain gently flowing water throughout the year, their sides are overgrown with grass and weeds, and they form permanent breeding places. *A. barbirostris* and *A. hyrcanus* were the commonest species found in these, though *A. minimus* and *A. culicifacies* were found on a number of occasions.

(2) *Hulas.* These are tortuous watercourses which form the natural drainage of the land, and which may contain either a rapidly running narrow stream or a broad swamp with no perceptible flow. There is generally a copious growth of water plants, such as 'Ikra,' 'Tora' and 'Nal,' in them, which may completely obscure the water. The anopheline fauna found in these varied according to the character of the water and the type of the vegetation. Where the water was slowly moving, and where there was dense vegetation overhanging and shading the water, *A. barbirostris* and *A. hyrcanus* were the chief species found. When the water was moving at a moderate pace, and where the vegetation was thin, some grass or weeds growing in the water but insufficient to form a cover over the water, *A. minimus* was generally found, such places proving to be its preferential breeding grounds. *A. culicifacies* was never found in any of these hulas.

(3) *Swamps*, consisting of a series of irregular pools of clean stagnant water with much grass and weeds, occur on the low bank of the river and in the beds of flat hulas. *A. culicifacies* and *A. minimus* were found in these.

(4) *Bheels.* These have in most cases been produced by a change in the course of the Desoi River, and have a curved shape in accordance with the original curvature of the river. Most of them are covered with long grass and plants such as cane, 'Ikra,' 'Tora,' 'Nal,' 'Katchu,' etc. The water is stagnant and tinged due to the constant shade and rotting vegetation. As a general rule these are harmless, no dangerous species breeding in them, though *A. minimus* was found on one occasion in the exposed portion of a bheel below Kaliapani lines.

(5) *Tanks and ponds.* These have been excavated as reservoirs for drinking water and engine water ; the banks are usually high, the edges bare, and the surface clean. On no occasion was any dangerous species found breeding in them and they may be regarded as quite harmless.

(6) *Borrow-pits*, from which earth has been removed for building purposes, etc. No dangerous species was found breeding in any of these at the time of our visit.

(7) *Temporary pools in the Desoi River bed.* Clean sandy pools are left when the river falls after any slight flood during the monsoon. *A. culicifacies* and *A. minimus* have been found breeding in them and they are undoubtedly of importance in influencing the amount of malaria in those lines built close to the river.

(8) *The Gohai jan.* Of the four fast flowing hill streams, Chirakhati, Kasojan, Gohaijan and Chingri jan, larvæ were found only in the Gohai jan at Bandersulia. This is a narrow stream coming out of the low hills to the south of Bandersulia, and

very active during the monsoon. In parts it is clear and free from vegetation and in parts it runs through dense jungle. *A. minimus*, together with *A. vagus*, *A. barbirostris* and *A. hyrcanus*, was found in it.

(9) *The Desoi River.* This is a fairly wide river with a strong current and silt-laden water. It is unusual to find larvæ in such a river and only a few *A. culicifacies* and *A. vagus* larvæ were found along the grassy edge where the current was feeble.

(10) *The Dholi Nadi.* This is an extremely tortuous rivulet fed by the Chirakhati and Naojank streams and a host of hulas from several tea gardens in the neighbourhood. It passes through patches of forest and jungle and has thick bushes on either side shading the water. In it only a few *A. barbirostris* larvæ were found.

(11) *Paddy fields.* At the time of our visit these were being tilled preparatory to planting the autumn crop; no water had yet accumulated in them and no collections of larvæ were therefore made from them. But from the work of other authors, and on epidemiological grounds, it is believed that they are quite harmless.

The factors influencing the severity of the malaria in the different lines.

The lines examined in this survey may be divided into three types, riverside lines, hillfoot lines and plains lines.

The riverside lines are the Kaliapani lines, Hatigarh lines, Desoi old and new lines, Kathalguri lines, Mariani II, IX, Christian and old lines and the Hunwal lines; all except the last, which is on the Chirakhati River, being on the Desoi River. The tortuous river running through soft alluvial soil repeatedly changes its course, eroding one bank and laying down land on the other with the result that there is left a high bank about fifteen feet high marking the extreme limit to which the river has ever travelled; below this is a low-lying stretch of land laid down by the river as it receded from the high bank. This low land, which may vary from a few feet to several hundred yards wide, is little, if any, above the high flood level of the river, and often slopes gently away from the river so that there may be either a swamp or a bheel at the foot of the high bank. The lines are generally built on the edge of the high bank to ensure easy drainage, and overlook the swamp or bheel at the foot, the condition of which determines the amount of malaria in the lines; if there is a definite permanent bheel, thickly overgrown with vegetation, and no shallow swampy areas overgrown with grass only, such as *A. culicifacies* prefers as a breeding ground, then the malaria is not severe and the spleen rate is low. This is the condition in Kathalguri. If, however, the depression in the ground is insufficient to form a bheel, and there are only shallow swampy areas at the foot of the cliff, perhaps drying up a week or two after rain, then the malaria is moderately severe, with a spleen rate of 50 to 60 per cent. Examples of this are Desoi and Hatigarh.

The chief dangerous anopheline of these riverside lines is *A. culicifacies*, breeding in swampy areas, pools in the river bed and in drains around the lines, while *A. minimus* may also be present, breeding either in neighbouring hulas, as in Kaliapani Munda lines, or occasionally in runnels connecting different portions of a swamp.

The hillfoot lines are Bandersulia and Keremiah, situated on a slope at the actual foot of the Naga Hills, with a number of streams running through them which are repeatedly flooded during the monsoon by the run-off from the hills, and also a number of small rivulets which probably remain sufficiently long after continuous rain to form dangerous breeding places. In these the chief dangerous anopheline is *A. minimus*, which breeds in the running streams and may be present in large numbers; *A. maculatus* is also present but in quite insignificant numbers compared to *A. minimus* and is relatively quite unimportant. These lines are intensely malarious with a spleen rate of about 80 per cent.

The plains lines comprise all those not mentioned in the former two groups. They lie in flat land, surrounded by tea, jungle or paddy, and with a varying number of hulas or streams running near them. The amount of malaria and the spleen rate in these lines show enormous variations, from very healthy lines with a spleen rate of 9 per cent to extremely unhealthy lines with a spleen rate of 93 per cent, the majority being over 50 per cent. *A. minimus*, which breeds preferably in clear running water, is the important anopheline in these lines, and it is on the proximity and number of breeding places of this species that the health of the lines depends. When they are few and distant very low spleen rates may be recorded; where a number of them lie in close proximity to the lines the spleen rate is very high. It may be said that if there is a hula or drain with permanent, exposed, clean running water in it within a hundred yards of the lines, the spleen rate is sure to be over 50 per cent, while those lines with several such hulas within a short distance, such as Nagadholie, Hatipara and Dhapatbari, are intensely malarious.

PREVENTIVE MEASURES.

Methods.

Measures for the prevention of malaria may take any or all of the following forms:—(1) avoidance of the bites of possibly infected mosquitoes; (2) the destruction of mosquitoes either in their adult or larval stage; (3) the removal of the source from which the anophelines become infected, and (4) the prevention of infection by the continuous quininization of all susceptible people.

(1) *Avoidance of the bites of possibly infected mosquitoes* is attempted by careful selection of the site on which new lines are to be built We are aware of the practical difficulty in doing this when new land is being opened, the labourers must live near to their work, and it is impossible to foretell the details of a site until a large amount of money has been spent on clearing it; but the majority of new lines are built on land which is already cleared, or partially cleared, and known. In these latter

cases any trouble or expense involved in making a careful preliminary survey of the potential dangerous breeding places on a site would be well repaid by the better health of the labour installed there.

In selecting a site the points requiring attention are the absence of potential breeding places of *A. minimus* and *A. culicifacies*, and in places away from the river this resolves itself into an avoidance of all perennial running hulas and streams. Suitable well drained sites are often to be found in areas of abandoned tea. The proximity of jungle or of paddy land does not appear to make a site unhealthy. If there are one or more hulas on the land selected, and it is impossible to choose another site, a band of the original thick bush sufficient to occlude the light should be left on either side of the hulas, thus making them unsuitable for *A. minimus*.

In gardens on the river bank it should not always be essential to perch the lines on the high bank of the river , if a site completely free from hulas and running water is available inland it would repay any extra expense involved in draining it to choose it rather than a potentially dangerous one on the river bank. Should it be considered necessary to build on the high bank attention should be paid to the features of the surrounding high ground, absence of hulas, etc., and to the nature of the low bank below the lines. If there is here a definite permanent bheel, thickly overgrown with coarse vegetation, and no shallow swampy areas, then the lines are likely to be healthy ; on the other hand, if there is a shallow grassy swamp, fed by rain water and seepage, then the lines will be unhealthy.

(2) *Destruction of mosquitoes*, in coolie lines, is possible only in their larval stage. On economic grounds it is advisable only to pay attention to the breeding grounds of known dangerous species, and they may be treated either by draining them, by making them unsuitable to the species breeding there, or by treating them with larvicides such as oil or paris green.

(*a*) *Anopheles minimus*, the most important species in these gardens, commonly breeds in drains and hulas containing clear water, preferably running, and exposed to the daylight. In the damp semi-tropical climate of Assam these are naturally covered with a dense growth of thick vegetation, which is of no economic value and makes the water unsuitable for this species. As a general rule this is cut down in the vicinity of coolie lines, either with the idea of improving the drainage, or as an anti-malaria measure ; for it is commonly believed that the dangerous mosquitoes breed in shaded stagnant water, and thus many of these harmless streams have been converted into dangerous breeding places. This growth should not be cut down but should be actively encouraged, especially plants which effectively shade the water without interfering with the natural run-off. *Polygonum flaccidum*, which has a narrow stem and forms a dense covering over the water, grows naturally in many of the smaller streams and drains, offering suitable shade and not interfering with the drainage, while in the larger streams *Eupatorium odoratum* fulfils the same purpose. The growth of vegetation of this type should be actively encouraged in all drains and streams around the lines ; if it is absolutely essential to clear the

stream to ensure adequate drainage, this should be done in the early part of the cold weather, so that there may be ample time for the growth to reappear before the next monsoon.

In some cases where the hulas run through coolie lines, and any vegetation planted would be rapidly destroyed, permanent measures, such as the training of the stream in a concrete channel, or diverting it away from the lines, are advisable.

The two larvicides which might be used in the breeding places of *A. minimus* are oil and paris green. Oil is well known, easily applied by almost unskilled labour, and the spreading can be checked by the appearance of oil on the water surface, but it has the disadvantage that it is incompatible with the method of biological control outlined above as it kills the vegetation in the water. Paris green, on the other hand, needs special appliances and more supervision, and the results cannot be checked with ease as it cannot be seen in the surface of the water. It, however, has no effect on the vegetation, and thus can be applied alongside biological methods; it is much cheaper in material costs than oil, and slightly cheaper in labour costs, and is therefore the larvicide of preference in this area.

Some experiments were carried out in Mariani to make sure that it would be effective in running water. These were unfortunately curtailed by a shortage of materials and delay in getting supplies from Calcutta, but sufficient evidence was obtained to show that it exerted a lethal effect in streams with a moderate rate of flow, such as the hula to the north of No. VIII lines in Mariani and the hula to the south of Dhapatbari lines. In streams with very rapid flow, such as the hula to the west of Bandersulia new lines, it is doubtful if it would be of value, and it may be necessary to use oil on these. As vegetation will never grow in the water in these rapid streams, the only objection that can be raised against the use of oil is its expense.

The use of larvicides on breeding places of *A. minimus* should be considered as a last resort only. The principal method of attack should be by making the water unsuitable for this species by the growth of vegetation; where this has failed, or has not yet been done, paris green may be used as a temporary measure.

For a description of the method of mixing and applying paris green reference should be made to Health Bulletin No. II, Malaria Bureau No. 3, by Major G. Covell (1930).

(*b*) *Anopheles culicifacies.* Those drains and streams in which *A. culicifacies* breeds will be made unsuitable by the same measures as are directed against *A. minimus*, but the swamps on the low river bank in which it, together with possibly *A. aconitus* and *A. maculatus*, breeds are less easily treated. If any of them are sufficiently high above the river level to afford a suitable slope for drainage, this might be done under expert engineering advice. The majority, however, are little if anything above flood level of the river, and would consequently be difficult to drain, and these must either be filled in or treated with larvicides. For breeding places of this type paris green is undoubtedly the best larvicide, being cheaper

and at least as effective as oil, and should be dusted over such swamps once a week throughout the malaria season from May to October.

(c) *Summary*. Measures directed against *A. minimus* should take the form of demarcation of the important and possibly important breeding places; treatment by biological methods making them unsuitable to dangerous species by encouraging the growth of overshadowing vegetation; and treatment of those places not yet well covered, or still breeding, by the application of paris green at weekly intervals throughout the malaria season from May to October.

Measures against *A. culicifacies* are similar to those against *A. minimus* when it is breeding in drains and hulas, and when breeding in swamps and pools, the regular application of paris green during the malarious months.

(3) *Removal of the source from which the anophelines become infected.* The common reservoirs of infection are the young children who have not yet acquired any immunity to malaria, and adults who have recently had an attack of malaria and have been insufficiently treated. An attempt is at present being made to remove the first source in Kathalguri by the regular quininization of all children under ten years of age. The results of this experiment in 1929 were hopeful but not definite, though it should be possible to give a definite verdict when the 1930 malaria season is over, and the morbidity figures for 1929 and 1930 can be compared with those of previous years. If it then appears that the experiment has been a success, it might be repeated in some of the other gardens.

An attempt should be made to remove the second source of infection, the adult who has recently had an attack of malaria but has been insufficiently treated, by the introduction of Sinton's (1930) standard course of treatment for all malaria cases, and by endeavouring to persuade all patients to complete the course.

(4) *The prevention of infection by the continuous quininization of all susceptible persons* has been tried in many estates in Assam. The almost universal verdict has been that, though some success may be achieved under experimental conditions, when supervision is strict, in normal conditions it is a failure because the majority of the coolies evade their dose of quinine. It is not therefore to be recommended.

Organization.

Some organization will be required to carry out the anti-larval measures to check the results and to deal with new breeding places as they appear. The Medical Association should fit up the laboratory opposite the Medical Officer's house with apparatus sufficient to examine and identify mosquitoes and their larvæ, and should employ a sub-assistant surgeon to be in sub-charge of this work under the Medical Officer. Under this man there would be six men of the compounder class, one employed by each company, except the Grob Tea Company and the Salonah Tea Company, who would share a man between them. The sub-assistant surgeon would be in general control of the anti-malaria work in every garden, and would examine and identify all collections of mosquitoes and their larvæ sent in to him

from the different gardens. He would visit each company once a week, by bicycle, inspect the work done by the compounder in the past week, and would himself examine and see treated the more important breeding places. The compounder would carry out the orders of the sub-assistant surgeon in making collections of larvæ from possible dangerous breeding places, and treating these when instructed to do so, to assist in which he would have one coolie permanently at his disposal, with two additional coolies during the malaria season.

To carry out this scheme detailed plans of work for each man will have to be made, all breeding places numbered and mapped, and note-books kept showing the dates on which each place was examined, what species of anopheline was found and what treatment, if any, applied. If this is done, it should be possible to make collections of larvæ from every potential dangerous breeding places once a week, and to treat all places found to be breeding regularly throughout the malaria season.

The compounder employed by the Grob and Salonah Tea Companies, whose work will be lighter than that of the others, might work as laboratory assistant to the sub-assistant surgeon in the afternoons at a small extra remuneration.

In addition to the pay of the sub-assistant surgeon, the compounders and the coolies mentioned above, this scheme involves the following expense: reconditioning of the laboratory at about Rs. 600, fitting out the laboratory at about Rs. 800 and building a house for the sub-assistant surgeon at about Rs. 1,000. Each company would have to provide apparatus for the distribution of paris green, at a total cost of about Rs. 150; the cost of materials used in anti-larval measures cannot be accurately estimated, as it varies with the amount of water to be treated, each acre of water surface treated with paris green costing about Rs. 2 per week. Thus if in any company ten acres were treated weekly for six months, this would involve an expense of Rs. 480 in materials.

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PART II.

NOTES ON INDIVIDUAL GARDENS.

DESOI AND PARBUTTI TEA COMPANY.

This company owns two large gardens, Daklingia and Kaliapani, and two out-gardens, Hatigarh and Moran Mathi, which are run in conjunction with Daklingia. Between the two main gardens runs the Desoi River; the Kaliapani lines are arranged on the Eastern bank, the Hatigarh lines on the Western bank, and the other lines are at some distance from the river.

Daklingia.

In this garden there are four sets of lines, the New and Old, which are near enough together to be treated as one, the Kandrakucha lines, the Dhobie lines, and the Epalsingh lines. The two out-gardens, Hatigarh and Moran Mathi, which each have one set of lines, will be dealt with together with the Daklingia lines as all their statistics are combined.

Health.

Daklingia is one of the most healthy gardens examined, with a very low spleen rate; Hatigarh and Moran Mathi are both less healthy than Daklingia, as judged by the spleen rates. Unfortunately the vital statistics of the three gardens are not separated, and it is therefore not possible to judge the relative amount of sickness in each, but the morbidity figures for the three gardens combined are well below those of most of the gardens examined.

Spleen and parasite rates: Daklingia.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
New and Old ..	85	18	21 per cent	20	6	30 per cent
Kandrakucha ..	88	8	9 ,,	30	4	13 ,,
Dhobie lines ..	13	2	(15 ,,)	..	..	..
Epalsingh ..	18	12	(66 ,,)	..	..	..
Hatigarh ..	52	25	48 ,,	50	24	48 per cent
Moran Mathi ..	9	5	(55 ,,)	..	..	..
TOTAL ..	265	70	26 ,,	100	34	34 per cent

Species and numbers of parasites : Daklingia and Hatigarh.

Species of parasite.	Parasite counts per c.mm.					Total.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	6	3	1	9	4	23
P. vivax ..	0	2	0	3	5	10
Mixed *P. falciparum* and *P. vivax*.	0	0	0	0	1	1

Vital statistics : Daklingia, Hatigarh and Moran Mathi.

	1926.	1927.	1928.	1929.	Average.
Birth rate	39	43	41	46	42
Death rate	33	30	33	30	31
New cases per 1,000, all causes	1,440	1,010	1,280	1,330	1,265
Sick days per 1,000, all causes	3,150	2,460	3,080	4,550	3,310

The figures for morbidity due to malaria alone are not available, but it is probable that this is low ; examination of the monthly returns for the last four years shows that there is not a great excess of cases during the malarious months of the year.

Seasonal distribution of new cases : Daklingia.

Year.	Population.	Number of new cases.		Excess in malarious months.
		December to May.	June to November.	
926 ..	3,041	1,004	3,360	2,356
927 ..	2,976	1,101	1,929	828
928 .	2,535	1,106	2,127	1,021
929 ..	2,486	1,271	2,054	783
verage	2,579	1,120	2,367	1,247

Even if we take the whole of the excess of cases during the malaria season as due to malaria this only gives an average case incidence of 412 per thousand per annum, a figure which compares very favourably with that of any other garden.

Breeding places and recommendations.

(1) The New and Old lines (population 738) lie in flat land much intersected by small tea drains, all of which become dry soon after rain and are harmless. Around the lines and near the factory are a number of borrow-pits containing water, and two water tanks, in none of which any dangerous species was found breeding. The two important breeding places are the hula arising in the Old lines and then going to the north beside the New lines, in which *A. minimus* was found breeding, and the hula beside the Jorhat Provincial Railway, in which *A. aconitus* was found. These two should be treated on the general principles recommended for hulas, by encouraging vegetation, and using paris green if necessary; that portion of the nullah which is actually in the Old lines should be trained in a pucca concrete or brick channel, as any vegetation planted here will be destroyed.

(2) The Kandrakucha lines (population 513) are on slightly raised ground with tea to the north and west, paddy land on the south, while on the east there is a thickly overgrown bheel which drains into an overgrown semi-stagnant hula. Both of these being well covered with vegetation no dangerous species was found breeding in them, or anywhere within three hundred yards of the lines, a fact which explains the extraordinarily low spleen rate of 9 per cent. No immediate measures are required here, but care should be taken that the bheel and the hula remain in their present condition.

(3) The Dhobie lines (population 50) lie to the north of the factory and are surrounded by tea. No dangerous species of anopheline was found breeding near them and the lines are consequently healthy with a spleen rate of about 15 per cent. No measures are needed in these lines.

(4) The Epalsingh lines (population 161) lie to the north-west, beside them is a small hula, with a central clear channel of water running in a wide swampy bed; *A. minimus* was breeding freely in this, which explains the higher spleen rate here, about 66 per cent. This hula will have to be treated on the lines recommended above, by encouraging vegetation in it, and by the application of paris green weekly until this has grown.

(5) Hatigarh (population 1,019) has only one set of lines which are built along the high bank of the river, from which they are separated by about a hundred yards of low land. After rain a swamp appears at the foot of the high bank, mainly as a result of seepage from above, and a series of grassy pools are formed. *A. aconitus* was found breeding in the seepage water and *A. culicifacies* in the pools at the side of the Desoi River. The nearest stream is that which passes Epalsingh, about four hundred yards away, though it is improbable that this has any effect on the malaria in Hatigarh; the most important sources of dangerous anophelines are the swamp below the lines and the pools beside the river.

There are three possible methods of dealing with the problem here: to drain this swamp; to treat it regularly with paris green throughout the malaria season; or to move the lines gradually away from the river. The last of these is by far the best method; as new coolies moved into the lines new houses should be built

for them on the western side, away from the river, and those houses on the riverside demolished. In this way it would be possible in a few years' time to move the lines from their present unhealthy site on to the patch of abandoned tea opposite them, which will prove far more healthy. If this is not done the swamp should be drained under expert supervision or treated with paris green weekly between May and October.

(6) Moran Mathi (population 54) is a separate small garden some distance to the west of Daklingia. The hula running in a westerly direction through the tea, about 150 yards south of the lines, contained *A. minimus* larvæ, and is the only source of dangerous anophelines in the vicinity. It should be treated by allowing a belt of jungle to grow on either side, sufficient to shade the water completely.

Kaliapani.

This garden lies on the eastern bank of the Desoi River, the lines being spread out in a long line along the top of the high bank, with a stretch of low alluvial land of varying width between them and the river.

Health.

The spleen and parasite rates are fairly high and the morbidity figures are slightly worse than those for other gardens with similar spleen rates.

Spleen and parasite rates : Kaliapani.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Munda	67	35	52 per cent	28	18	64 per cent
Oriya	20	19	66 ,,	29	14	48 ,,
Boyan	52	19	40 ,,	31	7	23 ,,
Dom	19	9				
TOTAL ..	167	82	55 ,,	88	39	44 ,,

Species and numbers of parasites found : Kaliapani.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	2	6	0	12	4	24
P. vivax ..	0	1	4	7	2	14
Mixed *P. falciparum* and *P. vivax*.	0	0	0	0	1	1

Vital statistics : Kaliapani.

	1926.	1927.	1928.	1929.	Average.
Birth rate	62	46	45	40	49
Death rate	53	31	30	31	36
New cases per 1,000, all causes	..	..	1,780	2,230	2,005
Sick days per 1,000, all causes	..	..	3,160	6,800	4,980

As in Daklingia the figures for the amount of sickness due to malaria alone are not available, but if we attempt to make an estimate in the same manner by taking the excess of the new cases in the malaria season over those in the non-malaria season we find the following result :—

Year.	Population.	Number of new cases.		Excess in malaria season.
		December to May.	June to November.	
1928 ..	1,156	676	1,165	489
1929 ..	1,167	521	2,086	1,565
Average ..	1,161	598	1,625	1,027

The malaria case incidence according to this would be 420 per 1,000 per annum in 1928, and 1,780 per 1,000 in 1929, with an average of 1,100 ; a much higher figure than that in Daklingia and on a level with that seen in most of the other estates.

Breeding places and recommendations.

The low-lying land between the lines and the river is partly marshy and partly cultivated, and holds a large horse-shoe-shaped bheel, marking a former course of the river. This bheel is for the most part overgrown with tall 'Tara' plants, but has at its sides some water which is clear of vegetation and in which *A. minimus* was found. Running behind the lines there is a deep hula, the Kaliapani Jan, with a permanent slowly running stream in the centre. *A. minimus* was found breeding in large numbers in this. In addition to these two important breeding places, *A. culicifacies* and *A. minimus* were found breeding in a small backwater of the river.

The Kaliapani Jan should be covered with thick vegetation, and an attempt made to prevent the coolies going down to the water, thereby breaking the vegetation down. Paris green should be applied weekly until breeding ceases. The main portion of the bheel under the lines requires no treatment, but the small

unshaded patches of water at its edges, and all swampy areas on the low bank, should be dusted weekly with paris green.

GROB TEA COMPANY.

Desoi.

This garden lies on the east bank of the Desoi River, near the place where it emerges from the Naga Hills. There are two coolie lines, the New and the Old, both built in very similar situations on the edge of the high bank, and with a stretch of about a hundred and fifty yards of low-lying land between them and the river; this land has a slight slope away from the river so that it does not naturally drain well, and at times it is liable to flooding.

Health.

The spleen and parasite rates show a considerable incidence of malaria, though the figures are not as high as in some of the other gardens. The morbidity figures for the only year available, however, are exceptionally high, there being more new cases recorded than in any other estate except Nagadholie. It is probable that this is to be explained by some other disease than malaria.

Spleen and parasite rates: Desoi.

Lines.	Spleens examined.	Spleens enlarged	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Old	72	45	62 per cent	40	20	50 per cent
New	63	44	70 ,,	40	20	50 ,,
Total garden ..	135	89	66 ,,	80	40	50 ,,

Species and numbers of parasites found: Desoi.

Species of parasite.	Parasite counts per c.mm.					Total.
	Over 5,000.	1,000–5,000.	500–1,000.	100-500.	Under 100.	
P. falciparum ..	1	4	4	8	5	22
P. vivax ..	0	0	1	7	4	12
P. malariæ ..	0	2	2	1	0	5
Mixed *P. falciparum* and *P. vivax*.	0	0	0	1	0	1

Vital statistics : Desoi.

	1926.	1927.	1928.	1929.	Average.
Birth rate	26	33	38	26	31
Death rate	21	16	16	12	16
New cases per 1,000, all causes	..	..	..	4,000	4,000
Sick days per 1,000, all causes	..	..	..	12,000	12,000

Breeding places and recommendations.

A. culicifacies and *A. minimus* were found breeding in the swamp below the Old lines and almost certainly they will breed in similar places near the New lines, though as our visit to these latter was made some time after rain they were not found by us. *A. culicifacies* was also found breeding along the edge of the Desoi River, though only in very small numbers, and this is probably of very minor importance. No dangerous species was found in the bheel under the New lines, and it should be left as it is with a thick growth of 'Tara' and 'Kachu' over it.

That part of the low bank, between the lines and the river, which is not permanently under water, should be given over to agriculture if possible, paddy land as at Kathalguri being less associated with malaria than uncultivated land as here and in Hatigarh. All shallow collections of water amidst the grass should be watched for dangerous anopheline breeding, and treated when necessary with paris green, which is undoubtedly the best larvicide for breeding places of this type.

In addition to these breeding places *A. culicifacies* was found in a drain passing the Manager's bungalow. This should be treated with a weekly application of oil as it is undoubtedly a danger to the health of the Manager and his family.

SALONAH TEA COMPANY.

Kathalguri.

This garden is on the bank of the Desoi River, the lines being arranged in a compact block on the high bank, with a semi-circular stretch of low-lying alluvial land between them and the river.

Sterilization of malaria carriers has been attempted here, since August 1928, by the issue of euquinine daily to children under ten years of age, the dose varying with the age of the child. Despite careful organization it is impossible to guarantee that every child gets its dose daily, but probably the majority get at least weekly doses. In 1929 there was an encouraging decrease in the number of malaria cases attending the hospital (308 per 1,000 in 1929 against 510 in 1928), but in a district so liable to annual variations in the severity of the malaria too much reliance should not be placed on the figures for a single year. It should be possible to give a definite verdict on the success of this experiment when the 1930 morbidity figures are

available. Up to the present the spleen rate has not been reduced, as is shown by the two spleen rates in the table below, which were taken at similar times of year, by the same man, before, and after the end of, the first year of treatment.

Results of annual muster: Kathalguri.

Lines.	Corrected spleen rate.	
	1927.	1929.
Bhokta	13·5	12·90
No. II	27·6	16·94
Tin	3·44	16·21
Riverside (kacheri) ..	20·46	5·75
Old	41·93	47·06
Aggregate of all lines ..	21·38	21·37

Health.

The spleen rates and morbidity figures show that this is one of the least malarious gardens examined, ranking with Daklingia and Titabar, though the figures for sickness due to all causes are not lower than in other gardens.

Spleen rates: Kathalguri.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.
No. V and Bhokta ..	35	8	23 per cent
No. II	24	3	12 ,,
Barra	40	10	25 ,,
Kacheri	30	6	20 ,,
Tin	13	2	15 ,,
Total for garden ..	142	29	20 ,,

Vital statistics : Kathalguri.

	1926.	1927.	1928.	1929.	Average.
Birth rate	41	54	40	33	42
Death rate	23	29	42	32	31
New cases per 1,000, all causes	..	..	1,440	1,310	1,375
Sick days per 1,000, all causes	..	..	9,800	8,700	9,250
New cases per 1,000, malaria	..	..	510	308*	409
Sick days per 1,000, malaria	..	..	2,850	1,280*	2,065

* Figures for the first ten months of 1929 only.

Breeding places and recommendations.

The lines, which form a compact block, are arranged along the high bank, at the foot of which there is a large horse-shoe-shaped bheel, covered with a dense growth of water plants; between this and the river is paddy land. On the landward side the lines are surrounded by tea, the nearest hula being some three hundred yards away. No dangerous anophelines were found breeding in the bheel or in the pools near the river; though, as *A. culicifacies* was found in the lines, it is probable that it breeds in the pools in the river bed at some time. *A. minimus* was found in the hula some distance away from the lines; that this is an important breeding place is shown by the fact that the old lines, which were built over the edge of it, were unhealthy, while the present lines, which are distant from it are far less malarious. It should be regarded as a source of minor danger to the coolies in the lines, and as a source of very real danger to the Manager and Assistant Manager, whose bungalows are very near to it. This hula should be grown over, and if necessary treated weekly with paris green; the water collections in the low-lying land, between the lines and the river should be examined regularly for *A. culicifacies*, and if this species is found, the breeding places should be dusted with paris green. No treatment of the bheel, which is harmless, is indicated.

HUNWAL TEA COMPANY.

The Hunwal Tea Company owns four gardens in the area under survey, Mariani, the main garden; Hattejuri, a small out-garden run in conjunction with Mariani; Nagadholie, and Hunwal which are worked separately.

Mariani.

The population of 1,337 is housed in nine different lines, which may be arranged in three blocks for our purpose, the lines in each block having similar malaria problems. One block consists of lines Nos. VIII, XIII, XIV, and IX; the second

consists of No. II lines and Christian lines: while the Old and Nadighat lines fall into the third group.

Health.

The first group of lines, which is by far the largest, is very malarious, with a combined spleen rate of 80 per cent, the second group is less malarious, with a spleen rate of 60 per cent, while the third group has a spleen rate of 47 per cent. The vital statistics include all occurrences in Hattejuri as well as in Mariani, but as this garden is very small in comparison with the main garden, and is about equally malarious, it is unlikely that this makes much difference to them; they show that the total amount of sickness in Mariani is well above the average for all the gardens surveyed, while the malaria morbidity is slightly over the average.

Spleen and parasite rates: Mariani.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.		Bloods examined.	Bloods positive.	Parasite rate.
VIII ..	41	32	78 per cent	80 per cent	31	13	42 per cent
XIII ..	39	35	90 „		26	14	54 „
XIV ..	16	10	(62 „)		15	5	(33 „)
IX ..	20	16	(80 „)		..	..	..
Christian ..	15	8	(53 „)	60 per cent	12	6	(50 per cent)
II ..	5	4	(80 „)		4	3	(75 „)
Old ..	10	3	(30 „)	47 per cent	10	5	(50 „)
Nadighat	9	6	(66 „)		2	1	..
Total garden	155	114	73 „		100	47	47 per cent

Species and number of parasites found: Mariani.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	0	5	5	14	10	34
P. vivax ..	1	0	0	4	3	8
P. malariæ ..	0	0	0	2	0	2
Mixed *P. falciparum* and *P. vivax*.	0	0	0	3	0	3

Vital statistics : Mariani.

	1926.	1927.	1928.	1929.	Average.
Birth rate	32	25	41	28	31
Death rate	22	16	24	18	20
New cases per 1,000, all causes	3,550	2,770	2,800	2,750	2,970
Sick days per 1,000, all causes	..	7,300	9,300	8,500	8,330
New cases per 1,000, malaria	630	470	570	560	557
Sick days per 1,000, malaria	2,100	1,580	2,180	1,700	1,890

Breeding places and recommendations.

(1) Lines Nos. VIII, XIII, XIV, and IX lie together on flat land through which run three hulas; (*i*) a large one to the north of No. VIII lines, perennial, cleared of vegetation in parts of its course and rapidly running; (*ii*) a small one running between lines Nos. XIII and VIII, which contains water only for a short time after rain, and (*iii*) a larger one in the recently cleared jungle to the south of lines No. XIV which contains running water for the whole of the wet season, and the banks of which have been cleared of all excess vegetation. To the west, south and south-east of these lines there is thick bush: a patch of abandoned tea, in which there is a series of streams and tanks lies to the east. *A. minimus* was found breeding in the hula to the north of No. VIII lines; the hula to the south of No. XIII lines is a probable breeding place for this species, though none were found in it at the time of our visit. No dangerous species was found breeding in the tanks and streams to the east of the lines, though the small running stream should be watched for the presence of *A. minimus*. The malaria in these lines is probably due to this species breeding in the two hulas mentioned on their boundaries together with possibly a slight infiltration of *A. culicifacies* from the bed of the Desoi River some three hundred yards away.

The hula to the north of No. VIII lines should be treated by encouraging the growth of vegetation over it in the manner recommended elsewhere. There is a stretch overgrown in this way about fifty yards to the west of the new hospital which will serve as a useful example of the type of growth which prevents breeding of *A. minimus*. As a hula so close to the lines is liable to have the growth around it trodden down by passers-by it should be protected by making a pucca bridge where the road along the west side of the lines crosses it. Cattle should be prevented from entering it by repairing the wire fence which protects part of it, and fencing those parts not already fenced. The hula on the south of lines No. XIII should be treated on smilar lines, and the hula running through the lines should be watched for *A. minimus*.

(2) No. II and Christian lines lie on either side of the road running north-west from the factory, surrounded by paddy land and jungle, and about a hundred and fifty yards from the Desoi River. The possible breeding places near to them are: a hula running behind the old hospital, clear, slowly running, and with grass-grown edges, in which *A. minimus* was found, and the pools which are left on the Desoi River bed after the subsidence of floods, in which *A. culicifacies* breeds. The malaria in these lines is probably due to both of these species; the hula should be treated on general lines described elsewhere, and pools on the river bed will have to be treated with paris green during the malaria season.

(3) The Old and Nadighat lines and clerks' quarters lie to the east of the factory, almost surrounded by jungle, about one hundred and fifty yards from the Desoi River, and a short distance from the series of streams and tanks mentioned in connection with the first group of lines. The malaria here is caused by *A. culicifacies* from pools in the river bed which should be treated with paris green during the malaria season.

Hattejuri.

This is a small out-garden lying to the south of Mariani and worked in conjunction with it. Although there are only 220 people on the estate, they are housed in four separate lines, which makes it difficult to take reliable spleen rates and to demarcate all the breeding places which might effect them.

Health.

The vital statistics, as mentioned before, are not separated from those of Mariani and therefore cannot be examined. The spleen rate is high and it is probable that there is a considerable amount of malaria here.

Spleen rates: Hattejuri.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.
Old	12	9	(75 per cent)
Bhustee.. ..	14	12	(86 ,,)
Uran	1	1	..
Total garden ..	27	22	81 per cent

Breeding places and recommendations.

The Old and Uran lines are close together on the east side of the garden, between the tea and apparently virgin forest; running through the tea and passing the

lines there are three permanent hulas which are quite clear of heavy vegetation in the tea, and are partly overgrown in the bush beside the lines ; in these *A. minimus* was found breeding.

The jungle lines are about a mile away from these, about a hundred and fifty yards from the Chirakhati hula, a permanent stream with a sandy bed and clean banks, in which no larvæ were found ; just behind the lines in the forest there is a small stream which might form a breeding ground for *A. minimus*. The Bhustee lines were not visited.

It would be uneconomical to carry out any anti-malaria operations in this garden, with the small population scattered in this way. If any new houses are to be built, a central healthy site should be chosen and the whole population gradually moved on to it. Until this is done the hulas beside the Old and Uran lines, and the stream behind the jungle lines should be treated on the general principles recommended.

Nagadholie.

The population of 626 of this garden is divided amongst four lines ; Nos. II, III and V form a fairly compact block and hold the majority of the inhabitants, while the Old lines with some thirty inhabitants are about two hundred yards away.

Health.

The vital statistics show an unusually unhealthy state of affairs. even for a garden with a high spleen rate. The figures for sickness due to malaria alone are slightly in excess of those in other gardens, but the total amount of sickness due to all causes far exceeds that in any other garden seen. This is chiefly due to diarrhœa and dysentery and we believe that anti-malaria measures in this garden, though important, are second in importance to general sanitary measures, such as the installation of a good water-supply, the preparation of latrines for the labour force, etc., intended to diminish the incidence of dysentery.

Spleen and parasite rates : Nagadholie.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
II and III ..	33	19	65 per cent.	33	15	46 per cent
V	50	39		48	22	
Old	13	10	(77 „)	..	..	..
Total garden ..	96	68	70 „	81	37	46 per cent

Species and numbers of parasites found: Nagadholie.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	3	4	6	13	7	33
P. vivax ..	0	1	1	1	1	4

Vital statistics: Nagadholie.

	1926.	1927.	1928.	1929.	Average.
Birth rate	24	32	25	23	26
Death rate	41	25	47	42	39
New cases per 1,000, all causes	6,050	5,900	2,350	2,180	4,120
Sick days per 1,000, all causes	20,300	13,600	14,300	12,200	15,100
New cases per 1,000, malaria	920	1,100	665	650	834
Sick days per 1,000, malaria	3,790	3,240	2,300	3,740	3,270

Breeding places and recommendations.

(1) The block consisting of Nos. II, III and V lines has near it two permanent hulas, one passing the south end of No. V lines, under the trolley line, and then running in a north-westerly direction to pass the western end of No. III lines and one passing the hospital, through a patch of jungle, then through the north-east corner of No. V lines and through No. III lines, finally joining the first stream. Both of these streams are slowly running, completely obscured in the parts where they pass through the jungle and exposed where they run close to the lines, in which latter parts *A. minimus* was found breeding. They are undoubtedly the cause of the malaria in these lines, and should be treated in the manner recommended for all hulas, by shading and paris green if required

(2) Behind the Old lines there is a small stream running through the jungle which might at times make a suitable breeding place for *A. minimus*, though none were found at the time of our visit. No dangerous species were found breeding in the tank beside the Manager's bungalow, the Dholi Nada or the hula to the north of the lines near the main road; the latter contains numbers of fish of the genus *Barbus*, which is extremely useful as a destroyer of mosquito larvæ. The number of people living in these Old lines is very small, and we understand that they will all eventually be moved into the other lines. In the meantime the hula behind the lines and that to the north should be watched for *A. minimus* larvæ and treated when found breeding.

Hunwal.

Hunwal lies near the foot of the Naga Hills and has running through it a fair sized perennial river, the Chirakhati, along which the lines are arranged, with paddy and tea on the landward side.

Health.

The spleen rates in both lines are high, and there is accordingly a considerable amount of sickness, though less than in any of the other gardens belonging to this company.

Spleen rates : Hunwal.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.
I	93	67	72 per cent
II	40	33	82 „
Total garden ..	133	100	75 „

Vital statistics : Hunwal.

	1926.	1927.	1928.	1929.	Average.
Birth rate	43	30	47	41	40
Death rate	30	15	32	16	23
New cases per 1,000, all causes	5,500	2,800	1,530	1,540	2,840
Sick days per 1,000, all causes	..	8,100	9,100	10,400	6,900
New cases per 1,000, malaria	480	157	390	520	387
Sick days per 1,000, malaria	2,920	1,100	1,520	1,690	1,810

Breeding places and recommendations.

The lines are arranged along the bank of the Chirakhati River. No larvæ were found in this at the time that we went to make collections from it; at a previous visit, however, anopheline larvæ had been found along the grassy bank. It is highly probable that these were *A. culicifacies*, which are found elsewhere breeding in similar situations, and which were found in the houses of No. II lines.

To the south of the lines a number of semi-stagnant drains run into the tea; in these *A. minimus* and *A. culicifacies* were found breeding.

To the south-east of the lines, behind the hospital, there is a small swamp from which a very small stream runs off to the north. No larvæ of any dangerous species was found in these.

The malaria in these lines is caused by *A. minimus* from the tea drains to the south, and *A. culicifacies* which breeds in these drains and almost certainly in river. The drains can be dealt with by a slight alteration in the level, so that they dry readily after rain, and by attention to the vegetation. In the case of the river it would be best to treat the extreme edges with oil once a week during the malaria season.

SCOTTISH ASSAM TEA COMPANY.

This company controls four gardens in the area under survey, Heleaka, Dhapatbari, Pangabari and Hattipatti, all lying to the south of the railway. some miles from the hills, and with no rivers near them.

Heleaka.

Heleaka is the main garden of the company ; the labour force of a thousand people lives in two lines, the Heleaka or Old lines, and the Halangkutti or New lines. Both of these are built on flat land. surrounded by jungle and tea which is intersected by hulas.

Health.

The spleen and parasite rates are moderately high, indicating a considerable amount of malaria, while the morbidity figures are about the same as in the majority of the other gardens.

Spleen and parasite rates: Heleaka.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Heleaka ..	91	60	66 per cent.	38	14	37 per cent
Halangkutti ..	70	48	69 „	22	10	45 „
Total garden ..	161	108	67 „	60	24	40 „

Species and numbers of parasites found: Heleaka.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000	100–500.	Under 100.	
P. falciparum ..	5	2	0	10	1	18
P. vivax ..	0	0	0	1	2	3
P. malariæ ..	0	0	3	0	0	3

Vital statistics: Heleaka.

	1928.	1929.	Average.
Birth rate	31	35	33
Death rate	28	26	27
New cases per 1,000, all causes	2,620	1,860	2,240
Sick days per 1,000, all causes	3,370	5,700	4,330
New cases per 1,000, malaria	860	665	762
Sick days per 1,000, malaria	1,540	1,042	1,291

Breeding places and recommendations.

(1) Heleaka lines. These are surrounded by jungle and tea; about five hundred yards to the north, between the Manager's bungalow and the hospital there is a large hula with steep banks, and with a rapidly running stream, clear of vegetation, in the centre. *A. minimus* was found breeding freely in this and in the tributary running through the Manager's compound. Immediately to the south of the lines there is a small stream running through the jungle, but cleared and exposed to the light in parts, which was also found to be breeding this dangerous species. Other possible breeding places in the vicinity of these lines are the numerous small drains taking origin just to the north of the lines and converging into a stream running westwards, which is at present well overgrown and not breeding; the stream running through the tea about a hundred yards to the east of the lines should be watched also. The hula near the hospital, and the stream to the south of the lines, should be treated by covering them with vegetation and by paris green if necessary, as recommended in Part I. The other possible breeding places mentioned should also be covered over and examined regularly for *A. minimus* larvæ and if these are found treated with paris green.

(2) The Halangkutti lines. These lie some five hundred yards to the west of the Heleaka lines, and are surrounded by tea; running through the centre of the lines there is a perennial stream which is clean of all vegetation and breeding *A. minimus* and *A. culicifacies*, those parts of it which run through the tea on either side of the lines are covered with vegetation and are not breeding any dangerous species. This is undoubtedly the cause of the malaria in the lines and should be dealt with by running it in a concrete channel through the lines, because any method of biological control, such as growth of shade, would probably be a failure as it would be so liable to damage by the inhabitants. If it is not trained in a concrete channel it should be treated with paris green weekly in the malaria season. The other small stream passing the south-east corner of these lines, which is at present completely overgrown and not breeding any dangerous species, should be kept in its present condition.

Dhapatbari.

This is a small out-garden of Heleaka, with a population of about three hundred and fifty, housed in one compact set of lines which have tea on three sides and jungle on the fourth.

Health.

This is the most unhealthy garden of those examined by us, judging by the spleen and parasite rates, which are extremely high; the morbidity figures, however, show an exceptionally small number of sick cases. This is probably due to the fact that there is no hospital on the estate, sick cases being treated in the hospital at Heleaka, and people will not trouble to report except when they are seriously ill.

Spleen and parasite rates: Dhapatbari.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Dhapatbari ..	58	54	93 per cent	58	40	69 per cent

Species and numbers of parasites found: Dhapatbari.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	2	11	4	10	6	33
P. vivax ..	0	0	2	3	0	5
P. malariæ ..	0	0	0	1	0	1
Mixed *P. falciparum* and *P. vivax*.	0	0	1	0	0	1

Vital statistics: Dhapatbari.

	1928.	1929	Average.
Birth rate	32	23	28
Death rate	14	28	21
New cases per 1,000, all causes	780	568	674
Sick days per 1,000, all causes	895	2 500	1,697
New cases per 1,000, malaria	182	162	172
Sick days per 1,000, malaria	298	367	332

Breeding places and recommendations.

Emerging from the jungle on the east and passing through the corner of the lines there is a small permanent stream. This is well covered with vegetation in the jungle before it passes into the lines, and once again well covered where it runs off into the jungle on the north, but the small portion in and close to the lines has been cleared and is breeding *A. minimus* freely. Running through the lines from east to west there is a very small stream which was not found breeding at the time of our visit but should be watched. Some fifty yards to the south there is a permanent stream running in a shallow swampy bed, which has been carefully cleaned, so that the stream occupies an open central channel with grassy edges, thus producing an ideal breeding place for *A. minimus*. Further to the south there are two very similar streams, also dangerous breeding places but less important on account of their greater distance from the lines.

The first hula mentioned, that passing through the north-east corner of the lines, might be dealt with by diverting it a little, so that it would not pass through the lines, running through jungle and tea only. It would thus not be liable to have the vegetation removed from its edges, as almost inevitably happens to any stream passing through coolie lines. The streams to the south of the lines should not be cleaned again, and should have vegetation along their banks actively encouraged; paris green should be applied in the malaria season until these measures have taken effect.

Pangabari.

Pangabari is a small out-garden with 225 inhabitants resident in a single compact lines, with tea on three sides and jungle and paddy on the fourth.

Health.

The spleen rate and vital statistics show a considerable amount of malaria.

Spleen rate: Pangabari.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.
Pangabari ..	37	32	86 per cent

Vital statistics: Pangabari.

	1928.	1929.	Average.
Birth rate	45	30	37
Death rate	45	17	31
New cases per 1,000, all causes	1,640	1,890	1,765
Sick days per 1,000, all causes	1,990	4,450	3,220
New cases per 1,000, malaria	620	667	643
Sick days per 1,000, malaria	955	1,490	1,222

Breeding places and recommendations.

A fair sized stream runs past the south-east corner of these lines, it is moderately fast, has grassy edges and no covering vegetation over it. Although no larvæ were found near the lines at the time of our examination, yet it seems to be a very suitable place for *A. minimus* and should be treated as dangerous, on the general lines recommended before. *A. minimus* was found in this stream about 400 yards from the lines. The small tributary which joins it on the east side of the village may be regarded as harmless, as it dries very rapidly after rain.

Hattipatti.

This garden is separated from the other gardens of the Scottish Assam Tea Company by one of the gardens of the Hunwal Tea Company, and has its own hospital. On the garden there are some five hundred people, in two sets of lines which are so near together that for our purpose they may be considered as one.

Health.

The lines are moderately unhealthy, with a spleen rate of 60 per cent, and morbidity figures which are about equal to the average for the gardens examined.

Spleen and parasite rates: Hattipatti.

Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
92	61	66 per cent	51	29	57 per cent

Species and numbers of parasites found: Hattipatti.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	3	3	1	8	3	18
P. vivax ..	1	3	1	1	1	7
P. malariæ ..	0	0	0	1	0	1
Mixed *P. falciparum* and *P. vivax*.	0	1	2	0	0	3

Vital statistics : Hattipatti.

	1928.	1929.	Average.
Birth rate	31	36	33
Death rate	30	24	27
New cases per 1,000, all causes	1,700	1,820	1,760
Sick days per 1,000, all causes ..	2,040	3,470	2,755
New cases per 1,000, malaria ..	657	770	710
Sick days per 1,000, malaria ..	735	995	865

Breeding places and recommendations.

In the neighbourhood of the lines there are four hulas: one to the north, two uniting near the lines to run in a north-westerly direction, and one passing the south-west corner of the lines. All of these are in places overgrown with thick vegetation, and in places clear of thick growth, and in these clear parts *A minimus* was found breeding. They should be treated by encouraging shading vegetation to grow over them, and by paris green if necessary.

TYROON TEA COMPANY.

Bandersulia.

This garden lies immediately at the foot of the Naga Hills, and has running through it a mountain stream, the Gohai Jan, and a number of small tributaries. The population of seven hundred is divided between three lines, the Old and New, close to each other, and the Karsulia lines some distance away.

Health.

This garden is very malarious, the spleen rates are high, and the vital statistics show an amount of sickness slightly above the average for the other gardens.

Spleen and parasite rates : Bandersulia.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Old and New ..	54	42	78 per cent	39	20	51 per cent
Karsulia ..	19	17	(89 „)	..	..	..
Total garden ..	73	59	81 „	39	20	51 per cent

Species and numbers of parasites : Bandersulia.

Species of parasite.	Parasite counts per c.mm.					Total.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	2	1	1	9	3	16
P. vivax ..	0	2	0	0	0	2
P. malariæ ..	0	0	1	1	0	2

Vital statistics : Bandersulia.

	1926.	1927.	1928.	1929.	Average.
Birth rate	31	52	22	30	34
Death rate	29	33	45	39	36
Sick days per 1,000, all causes	5,680	8,340	8,000	7,500	7,400
Sick days per 1,000, malaria	1,680	860	1,730	1,600	1,470

Breeding plaees and recommendations.

(1) Old and New lines. The chief features of these are the Gohai Jan running to the east of the New lines and thence into a patch of jungle beside the Old lines ; a large artificial nullah running down the west side of the New lines and joining the Gohai Jan opposite the Old lines : a broad hula some hundred yards to the west of the Old lines in the tea, and a series of small drains running from east to west through the New lines into the artificial nullah. *A. minimus* was found breeding both in the Gohai Jan and the nullah on the other side of the New lines, although these two are very liable to flooding and had been flooded a short time before our visit. The hula in the tea to the west is harmless if left in its present condition, overgrown with vegetation, while the drains running through the New lines are possible breeding places that will have to be watched. As a result of the presence of the two good breeding places for *A. minimus* on either side of the New lines this species was very numerous in the houses.

Adequate treatment of these streams which are so liable to flooding is difficult ; they normally have a good current in them, which is probably too great to allow paris green to be effective and no vegetation such as 'Kuchu' can grow in them. The dense jungle should not be cleared away from the side of the stream to the east of the Old lines, and the part passing the New lines, which has been cleared, should be oiled weekly. No treatment of the hula running in the tea to the west is indicated, it should be left in its present condition, and the small drains running through the New lines should not be treated until they are actually found to be

breeding some dangerous species, when they should either be put in cement drains, or treated weekly with paris green.

(2) The Karsulia lines. These lines have a very small population and are surrounded by dense jungle. The malaria carrier was not identified, and its breeding places not found.

Keremiah.

This is an out-garden of Bandersulia, lying some miles to the east, at the foot of the hills, and surrounded by dense jungle, a fair sized mountain stream, the Kasa Jan, lies to the west of the lines. The population of four hundred and fifty is housed in one compact set of lines.

Health.

This garden is unhealthy, the spleen rate is high, and the morbidity due to malaria is well above the average.

Spleen rate: Keremiah.

Lines.	Spleens examined	Spleens enlarged.	Spleen rate.
Keremiah ..	59	47	80 per cent

Vital statistics: Keremiah.

	1926.	1927	1928	1929.	Average.
Birth rate	22	37	25	46	32
Death rate	24	24	18	13	20
Sick days per 1,000, all causes	..	..	7,730	7,450	7,590
Sick days per 1,000, malaria	..	..	2,250	2,570	2,410

Breeding places and recommendations.

On the west of the lines is the Kasa Jan; on the east is a small stream, and a drain runs through the centre turning off to the west to join the Kasa Jan No larvæ were found in the Kasa Jan, the current being too strong, but *A. minimus* was found in both of the other streams mentioned. At the points where these cross a road, the vegetation is beaten down by persons crossing them and good breeding places for *A. minimus* are created; they are harmless in the greater part of their course where the vegetation has not been broken down. At these places where the vegetation is liable to be beaten down they might be put in concrete drains, with a slab over the top. Other parts should be treated in accordance with general recommendations for hulas.

TITABAR TEA COMPANY.

Titabar.

This garden is situated in flat land, not much intersected by hulas, and well drained. The population of 418 people is divided into three lines, the Oriya, Jabbalpori and Bhalua lines; the first two of these are sufficiently near to each other to be treated together, while the Bhalua lines, which are very small, with a population of about forty, lie about half a mile away.

Health.

Judging from the spleen rates, given in the table below, the lines are healthy, but unfortunately the vital statistics are not separated from those of the other two gardens owned by this company, so that the morbidity rates cannot be compared.

Spleen and parasite rates: Titabar.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Oriya and Jabbalpori	49	9	18 per cent	49	9	18
Bhalua ..	5	3	(60 ,,)	..	..	..
Whole garden ..	54	12	22 ,,	49	9	18

Species and number of parasites found: Titabar.

Species of parasite.	Parasite counts per c.mm.					Total.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	1	1	0	1	2	5
P. vivax ..	0	0	0	2	1	3
P. malariæ ..	0	0	0	0	1	1

Vital statistics: Titabar, Moheema and Hatipara combined.

	1926.	1927.	1928.	1929.	Average.
Birth rate	36	45	31	41	38
Death rate	28	26	44	24	30
New cases per 1,000, all causes	2,730	2,850	3,340	3,200	3,030
Sick days per 1,000, all causes	..	..	.	9,400	9,400
New cases per 1,000, malaria	710	780	1,030	1,020	995

Breeding places and recommendations.

(1) The Oriya and Jabbalpori lines are surrounded by jungle and paddy land not greatly cut up by streams, there being only one important nullah which runs to the south of the Oriya lines, and thence between the Oriya and the Jabbalpori lines. This nullah had been recently cleaned when we examined it, the part between the two lines being so clean that there was not a blade of grass left. No anopheline larvæ were found in this part, but *A. minimus* was found to the south. where it had only been partially cleaned, and to the north, where it runs through the corner of the Jabbalpori lines. No dangerous species was found in any of the drains in the lines, or in the water tank. The nullah should be treated by encouraging shading vegetation, as detailed before, while that part actually running through the Jabbalpori lines should either be put in a concrete drain or treated weekly with paris green.

(2) The Bhalua lines lie about half a mile to the south-east of the main lines and are surrounded by tea and jungle. The nullah mentioned in the description of the Oriya and Jabbalpori lines passes close to them, and is a potential breeding place, though no *A. minimus* larvæ were found beside the Bhalua lines at the time of our visit. The treatment required is the same as that recommended for this nullah in the lower part of its course.

Moheema.

In this garden the population of 293 is housed in one long line surrounded by jungle and paddy land.

Health.

The spleen and parasite rates show a moderate amount of malaria ; the vital statistics are not kept separately for this garden.

Spleen and parasite rates : Moheema.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Moheema ..	34	17	50 per cent	34	11	32 per cent

Species and numbers of parasites : Moheema.

Species of parasite.	Parasite counts per c.mm.					Total.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	1	3	2	2	0	8
P. vivax ..	0	0	1	1	0	2
P. malariæ ..	0	0	0	1	0	1

Breeding places and recommendations.

There are a number of small and harmless drains running through the lines ; a larger drain to the west running through the Bhustee lines, and two drinking water tanks, in none of which any dangerous species of anopheline was found. The important places in which *A. minimus* breeds are three semi-permanent streams which run to the east of the lines, and which should be treated on the general lines recommended in Part I.

Hatipara.

This garden has at present a population of 248, which will probably be increased as new ground is being opened up. The labour force is divided into two lines, the Oriya and Munda, about half a mile apart.

Health.

Both of the lines on this garden are highly malarious, showing unusually high spleen and parasite rates ; morbidity figures, as mentioned before, cannot be compared as they are not kept separately.

Spleen and parasite rates : Hatipara.

Lines.	Spleens examined.	Spleens enlarged.	Spleen rate.	Bloods examined.	Bloods positive.	Parasite rate.
Oriya	12	12	(100 per cent)	9	4	(44 per cent)
Munda	28	23	82 ,,	27	21	78 ,,
Total garden ..	40	35	87 ,,	36	25	69 ,,

Species and numbers of parasites : Hatipara.

Species of parasite.	PARASITE COUNTS PER C.MM.					TOTAL.
	Over 5,000.	1,000–5,000.	500–1,000.	100–500.	Under 100.	
P. falciparum ..	3	2	1	10	5	21
P. vivax ..	0	1	2	0	0	3
P. malariæ ..	0	0	0	1	0	1

Breeding places and recommendations.

(1) The Oriya lines are in a long line beside the road ; emerging from the tea on the east, close to the dispensary there is a permanent clear, fairly rapidly running stream, which goes behind the lines, and runs in a shallow and marshy bed parallel and very close to them, finally recrossing the road to the west of the lines. *A. minimus* was found breeding freely in this stream, the close proximity of which

to the lines is the cause of the high spleen rate found. It should be dealt with by shading the water and by weekly applications of paris green until the breeding has ceased.

(2) The Munda lines are in process of construction on recently cleared land; the site is much cut up, there being three running streams near to it and a number of 'blind hulas' all over the area which is to be built on. *A. minimus* was found breeding freely in the following hulas: (*i*) the clean running stream emerging from the jungle at the south-west corner of the lines, then passing under the wooden bridge on the road from the Oriya lines, and thence under the garden road going west; (*ii*) the hula running parallel to the lines but on the other side of the nursery, then turning north and running through the lines, and (*iii*) the large hula to the east, which is at present only cleared in parts, but will soon be completely cleared and will become a very dangerous breeding place.

As a result of the close proximity of these three bad breeding places the lines are already unhealthy, and if many new coolies are drafted in, a serious outbreak of malaria may be confidently expected. Steps should be taken as soon as possible to make these unsuitable for *A. minimus*; the hula (*ii*) mentioned above might be connected with the other hula on the west, thus diverting the water which at present flows right through the lines. The bed of the hula within the lines thus dried would have to be filled in to prevent water accumulating in it or running along it. No more jungle than is necessary should be removed from the banks of the other two hulas and those parts already clear should be allowed to become grown over again and treated with paris green if necessary.

APPENDIX.

SCHEDULE OF ANOPHELINES OBTAINED IN DIFFERENT ESTATES.

TABLE A.

Numbers of different species of anopheles caught in houses.

Estates.	Lines.	1 *aconitus.*	2 *aitkenii.*	3 *barbirostris.*	4 *culicifacies.*	5 *fuliginosus.*	6 *hyrcanus.*	7 *kochi.*	8 *leucosphyrus.*	9 *maculatus.*	10 *minimus.*	11 *philippinensis.*	12 *tessellatus.*	13 *vagus.*
Daklingia ..	Old and New	..	..	..	..	..	..	..	..	..	1	..	..	34
	Kandrakucha	..	..	..	..	..	..	..	..	..	..	..	..	25
	Epalsingh ..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Hatigarh ..	..	..	..	1	..	..	..	..	..	..	..	..	8

TABLE A—*contd.*

Estates.	Lines.	1 *aconitus.*	2 *aitkenii.*	3 *barbirostris.*	4 *culicifacies*	5 *fuliginosus.*	6 *hyrcanus.*	7 *kochi.*	8 *leucosphyrus.*	9 *maculatus.*	10 *minimus.*	11 *philippinensis.*	12 *tessellatus.*	13 *vagus.*
Desoi ..	Old ..	..	..	..	4	1	11	..	..	..	..	..	..	118
	New .	..	..	..	2	..	13	..	..	..	..	..	..	63
Kathalguri ..	Old (Barra) ..	..	..	..	3	..	2	..	..	..	3	..	..	16
	II, V, and Tin	..	..	..	4	..	2	1	..	..	5	..	..	108
	Riverside ..	..	..	.	..	.	..	..	..	..	..	1	..	27
Mariani ..	VIII ..	..	..	1	1	2	7	..	..	..	1	..	1	59
	XIII and XIV	..	..	..	.	1	2	..	..	..	1	..	..	38
	IX and Old ..	..	..	..	2	..	..	..	..	..	2	..	..	45
	II and Christian	..	..	..	..	1	12	..	1	1	2	4	..	12
Hattejuri ..		..	..	..	..	..	..	1	..	.	..	..	..	4
Hunwal ..	I ..	..	..	..	..	..	20	..	..	..	4	..	..	88
	II ..	..	..	..	5	2	6	..	..	..	5	2	..	43
Nagadholie ..	III and V ..	..	..	..	..	2	..	..	..	..	4	..	..	9
	II and Babus	..	..	..	.	..	..	..	..	..	..	..	..	4
Hattipatti ..		.	..	..	9	1	1	..	..	..	67	..	..	70
Dhapatbari ..		..	..	..	..	..	1	1	.	..	4	.	..	57
Pangabari ..		..	..	..	..	1	..	1	..	..	..	1	..	28
Heleaka ..	Halangkutti ..	..	..	..	5	..	..	..	..	..	..	..	1	54
	Heleaka ..	1	..	..	14	2	1	..	..	..	6	..	..	117

TABLE A—*concld.*

Estates.	Lines.	1 *aconitus.*	2 *aitkenii.*	3 *barbirostris.*	4 *culicifacies.*	5 *fuliginosus.*	6 *hyrcanus.*	7 *kochi.*	8 *leucosphyrus.*	9 *maculatus.*	10 *minimus.*	11 *philippinensis.*	12 *tessellatus.*	13 *vagus.*
Bandersulia ..	New ..	..	..	..	..	..	2	..	..	..	130	..	..	16
	Old ..	..	..	..	..	..	..	..	..	..	38	..	..	8
	Karsutia ..	..	..	..	..	..	..	..	..	..	..	..	..	..
Keremiah ..		..	..	..	..	..	7	..	..	..	2	..	..	2
Titabai ..	Oriya ..	..	..	2	..	..	..	..	..	..	2	..	..	47
	Jabbalpori ..	..	..	1	..	..	..	..	..	..	..	..	..	126
	Bhalua ..	..	..	2	..	1	..	..	..	..	..	..	..	2
Hatipara ..	Oriya ..	..	..	1	1	..	12	4	..	..	6	..	..	18
	Munda ..	..	..	..	..	..	17	..	..	..	6	..	..	16
Moheema ..		..	..	..	6	2	1	..	..	..	8	..	..	49

TABLE B.

Different species of anopheline larvæ collected in their breeding places.

Estates.	Lines.	1 *aconitus.*	2 *aitkenii.*	3 *barbirostris.*	4 *culicifacies.*	5 *fuliginosus.*	6 *hyrcanus.*	7 *kochi.*	8 *leucosphyrus.*	9 *maculatus.*	10 *minimus.*	11 *philippinensis.*	12 *tessellatus.*	13 *vagus.*
Daklingia ..	Old and New ..	2	..	..	..	24	28	..	..	..	7	2	..	30
	Kandrakucha ..	..	..	11	..	..	10	..	..	..	..	..	..	16
	Epalsingh ..	4	..	..	..	..	9	..	..	..	9	..	..	8
	Hatigarh ..	5	..	..	3	..	18	6	..	..	..	..	..	25

TABLE B—*contd.*

Estates.	Lines.	1 *aconitus.*	2 *aitkenii.*	3 *barbirostris.*	4 *culicifacies.*	5 *fuliginosus.*	6 *hyrcanus.*	7 *kochi.*	8 *leucosphyrus.*	9 *maculatus.*	10 *minimus.*	11 *philippinensis.*	12 *tessellatus.*	13 *vagus.*
Moran Mathi ..		..	..	11	..	..	37	6	..	..	10	17	..	..
Kaliapani .	Munda ..	..	..	9	..	..	13	..	..	..	48	..	..	16
	Oriya ..	..	..	..	6	..	17	..	..	..	6	..	..	2
Desoi ..	Old	..	..	4	17	..	59	21	..	..	6	..	..	69
	New ..	..	..	..	9	..	..	..	..	..	..	..	..	6
Kathalguri ..	Old (Barra) ..	..	..	39	..	..	82	28	..	..	6	..	..	62
	II, V and Tin ..	..	..	15	..	4	43	18	..	..	..	..	..	..
	Riverside ..	..	..	..	..	..	36	10	..	..	..	14	..	36
Mariani ..	VIII ..	..	..	31	..	..	77	13	..	..	4	7	..	43
	XIII and XIV ..	..	..	7	..	..	27	14	..	..	..	..	..	19
	IX and Old ..	..	..	50	23	..	28	..	..	..	..	6	..	43
	II and Christian	..	..	24	8	..	18	5	..	..	4	..	..	10
Hattejuri ..		..	..	82	..	..	46	..	..	..	5	..	..	29
Hunwal ..	I	..	..	30	20	..	28	16	..	..	4	2	2	12
	II	..	..	..	..	..	..	..	..	..	..	..	..	..
Nagadholie ..	III and V	..	..	74	..	..	34	..	1	..	24	..	..	12
	II and Babus ..	..	..	38	..	..	34	4	..	..	..	4	..	10
Hattipatti ..		..	..	59	..	31	20	8	..	..	26	4	..	20
Dhapatbari ..		..	..	88	..	2	97	31	..	..	17	10	..	48
Pangabari ..		..	..	45	..	6	39	41	..	..	4	..	2	43

TABLE B—*concld.*

Estates.	Lines.	1 *aconitus.*	2 *aitkenii*	3 *barbirostris.*	4 *culicifacies.*	5 *fuliginosus.*	6 *hyrcanus.*	7 *kochi*	8 *leucosphyrus.*	9 *maculatus.*	10 *minimus.*	11 *philippinensis.*	12 *tessellatus.*	13 *vagus.*
Heleaka ..	Halangkutti ..	..	..	40	14	12	60	31	..	..	14	4	..	38
	Heleaka ..	..	..	49	..	..	68	5	..	..	18	29	..	10
Bandersulia ..	New ..	..	.	8	..	..	22	14	..	1	10	..	..	44
	Old	..	..	6	..	..	4	..	..	..	3	..	..	2
	Karsulia ..	..	.	25	.	2	17	5	..	..	..	4	..	..
Keremiah ..		..	..	39	..	.	42	19	..	..	18	2	..	6
Titabar ..	Oriya ..	..	..	15	..	8	.	..	..	..	..	..	..	6
	Jabbalpori ..	..	..	15	9	3	20	6	..	..	8	12	..	15
	Bhalua ..	..	..	6	..	..	45	..	..	..	..	..	..	..
Hatipara ..	Oriya ..	..	2	8	..	6	22	..	..	..	21	..	..	15
	Munda ..	..	.	47	..	..	32	6	..	..	33	6	1	4
Moheema ..		..	..	8	..	..	68	2	..	..	14	2	..	38

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NOTES ON SOME ENTOMOLOGICAL TECHNIQUE FOR THE MALARIOLOGIST.

BY

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[21st December, 1930.]

1. THE TRANSMISSION OF *Anopheles* LARVÆ THROUGH THE POST.

THE following method for sending specimens of larvæ through the post has been tested during the past year and the results have proved very satisfactory. A specimen tube $2\frac{1}{2}$ inches $\times$ 1 inch, or 3 inches $\times$ 1 inch, is prepared by pushing a wad of cotton-wool, soaked in formalin, down to the bottom, and this is held firmly in place by a disc of cork. The disc should be about $\frac{1}{4}$ inch thick as, if it be too thin, it will warp and shake loose. The disc may conveniently be cut from the lower end of the cork supplied with the tube, but care must be taken to see that it fits the tube very tightly. The wad of cotton-wool should be about $\frac{1}{2}$ inch thick when firmly pressed down. Sufficient formalin should be used so that when the cork disc is forced down on to the wool it will become saturated with the liquid, any excess being afterwards poured off.

Larvæ are transferred to the tube, from water, either with a spoon or with a wide-mouth pipette ; 30 or 40 larvæ may be placed in one tube. *All the water* is then poured off, or drawn off with a pipette, leaving the larvæ stranded on the cork disc or on the sides of the tube. The open end of the tube is then firmly corked, the tube done up in cotton-wool, or soft paper, and packed in a wooden box. The larvæ are very soon killed by the formalin vapour and remain attached to the cork disc, or the sides of the tube, quite firmly, and there is very little risk of their being shaken about.

Numbers of larvæ have been received at Kasauli, in such tubes, from various parts of India including Wana, Razmak, Sind, Patiala, Singhbhum and Mysore. When received, they are carefully washed out of the tube with water, placed on a slide in a little water, and identified under the microscope. As a rule, if the larvæ have been carefully handled in the first place, they arrive in perfect condition, and may be mounted as permanent preparations if required. The formalin does not

usually cause shrinkage, the mouth brushes of the larvæ are often folded beneath the head, thus showing the two pairs of anterior clypeal hairs to advantage, and the palmate hairs are usually well displayed.

Some larvæ were sent by letter post, in such tubes, to Dr. Buxton, London School of Tropical Medicine, and another lot to Professor Patton, Liverpool School of Tropical Medicine, and they both reported that the larvæ arrived in good condition for mounting.

This method is also useful when making collections of larvæ on tour. The tubes may be numbered on the cork and particulars kept in a note book, or a label may be pasted on the outside of the tube giving the necessary data. So long as the tubes are kept properly corked, larvæ will remain in good condition in them for weeks or even months. If possible, the corks should be sealed with hard paraffin. Culicine larvæ may, of course, be transported in a similar manner.

The method described appears to be preferable to the more usual one of sending specimens of larvæ in alcohol or other preservative fluid. If the tubes are not completely filled or should there be even a small bubble present, the larvæ are bound to be subjected to much shaking about with consequent damage to the hairs which are of importance in identification.

2. Rearing *Anopheles* from the egg.

It is not claimed that the technique here described is the best that could be devised for rearing *Anopheles* from the egg, nor that it is new or original. It is, however, a fairly simple method and does not require much time or attention. As it does not seem to be very generally known, it has been thought worth while to give details of the method which has been used successfully at certain times of the year at Kasauli and Karnal, Punjab, for rearing large numbers of 4th stage larvæ and adults for the Malaria Survey collections and for the use of students at the malaria class. The breeding has been done chiefly during the pre- and post-monsoon periods when there is usually continuous sunshine for long periods.

Gravid female *Anopheles* are selected and confined in lamp globes. For single specimens 'Boy Globes,' 4 inches × 2¼ inches, obtainable in Calcutta, are very suitable; for numbers of specimens ordinary hurricane lamp globes are used. The upper end of the globe is covered with mosquito netting upon which are placed some raisins and a strip of lint, the latter being kept continuously damp. A receptacle containing water is placed inside the lower end of the globe. Some grass stems may be pushed into the globe beforehand to afford resting places for the mosquitoes. The globes should be kept in a dark place free from ants. Should the temperature be very low, the globes may be kept in an incubator at about 20 to 22°C.

It has been found that some species, e.g., *A. pulcherrimus*, will not readily lay in confinement, but eggs may usually be obtained by a method used by Mr. P. G. Shute, of the Ministry of Health, Horton, Epsom, England. The gravid mosquito is transferred to a test tube and then allowed to fall from the tube on to the surface of water. Frequently it will commence to lay within a few minutes.

If the mosquito be very active, it may be partially stunned by rapping the tube smartly against the hand and the mosquito then allowed to fall on to the water.

Soon after the eggs have been laid, they are transferred with a camel-hair brush to water in a bowl, basin or dish. The best results have been obtained with glass petri dishes 8 to 10 inches in diameter. The eggs are floated within a hollow square of cork coated with hard paraffin, as recommended by Macgregor, 'Mosquito Surveys,' p. 224. This prevents the eggs from becoming stranded on the side of the vessel during evaporation of the water. Some *Spirogyra* and a plant of grass, with some soil attached to the roots, are added, and, as soon as the larvæ hatch, some chopped flies are scattered on the surface of the water. The *Spirogyra* should be kept in a basin for some time previously and exposed to sunshine, search being made from time to time for any eggs, larvæ, or other living creatures and these removed. *From now onwards the dishes containing the larvæ are kept in the sun, during the early morning hours, or for several hours during the day.* This is the most important part of the technique. The sun causes bubbles of oxygen to form in the *Spirogyra* which keep the water aerated and prevent a scum forming on the surface. The grass plant affords shade and shelter to those larvæ which prefer this condition to direct sunlight.

If convenient, the dishes are examined about midday, when some cool water and more food material are added if necessary. About 4 or 5 P.M. the dishes are put away for the night and are covered with another petri dish, or sheet of glass to prevent other mosquitoes from laying eggs upon the water. It should be mentioned that on no account should the dishes be covered when exposed to sunshine.

The time occupied in rearing larvæ by this method is usually not more than 15 to 30 minutes daily, according to the number of dishes to be handled, and the work can be done by an assistant with occasional supervision.

Numbers of 4th stage larvæ of the following species of *Anopheles* have been raised from the egg by this method : *fuliginosus*, *pallidus*, *culicifacies*, *stephensi*, *pulcherrimus*, *listoni*, *subpictus*, *turkhudi*, *lindesaii*, *maculatus*, *maculipalpis* and *hyrcanus*.

The method has been used more especially for raising the maximum amount of material with the minimum expenditure of time and trouble. Detailed figures have not been kept in most cases of the number of larvæ raised from a given number of eggs, but the mortality noticed has been small. In one case 132 fourth stage larvæ of *A. lindesaii* were taken from a dish in which 160 eggs had been placed ; in another case 62 fourth stage larvæ of *A. maculatus* were taken from a dish in which 100 eggs had been placed. It was not known, in either case, how many of the eggs actually hatched.

3. The transmission of living mosquitoes through the post: further results.

The method described previously (Barraud, *Ind. Jour. Med. Res.*, XVII, 1929, pp. 281—285) has been put to various uses during the past year with satisfactory

results. In March 1930, at the commencement of the Malaria Class in Karnal, difficulty was experienced in obtaining living adults of certain species of *Anopheles* in sufficient numbers for the use of the students, *A. culicifacies* being particularly scarce. Arrangements were therefore made for consigments of living adults of this species to be sent from Larkana, Sind, where Sub-Assistant Surgeon Subedar J. D. Baily was in charge of the Sind Malaria Inquiry. A number of boxes were received at Karnal and more than sufficient living *A. culicifacies* were obtained.

In April a batch of 34 bred specimens of the same species, 9 of which had been fed on normal blood, were sent by Air Mail to Lieut.-Colonel S. P. James in London, who required them for experimental purposes. The journey occupied 11 days. The box was broken on arrival in London and appeared to have been opened, nevertheless 9 specimens were still alive in the cage. Attempts were immediately made to feed these on malaria cases, but as the diverticula of all the specimens were filled with water of fruit juice, they refused to feed. Being bred specimens and unfertilized, no breeding from them could be attempted.

In September Major J. A. Sinton, I.M.S., forwarded some boxes of living *Anopheles* (mostly *culicifacies*) from Kothala, Gujerat district, Punjab, to Karnal. These were dissected and some found to be infected with malaria parasites.

From September up to the time of writing in December, a large number of boxes of living mosquitoes have been received at Kasauli and Karnal, the largest number being sent by Mr. K. Bose. Honorary Secretary, Birnagar Palli Mandali, from Birnagar, Bengal. Other boxes were received from Dr. M. D. Engineer through the Superintendent, Andhra Valley Power Company near Bombay, the Officer Commanding, Indian Military Hospital, Chakdara, N. W. F. P., Mr. M. O. T. Iyengar of Calcutta, from Budge-Budge. Dr. Ananthaswamy Rao, from Mudigere, Mysore State, Jemadar Harbhagwan, from Jeypore Town and Captain B. S. Chalam, from Bengal. In some cases the boxes were several days in the post but in nearly all instances, where the boxes had been properly packed, the proportion of surviving specimens was about 80 per cent of the total number sent.

In all about 1,500 living *Anopheles* were received in a little more than three months, and eggs, for descriptive and breeding purposes, were obtained from the following species: *aconitus*, *barbirostris*, *culicifacies*, *fuliginosus*, *hyrcanus*, *jamesii*, *jeyporiensis*, *lindesaii*, *listoni*, *ludlowii*, *maculatus*, *maculipalpis*, *moghulensis*, *pallidus*, *philippinensis*, *pulcherrimus*, *ramsayi*, *stephensi*, *subpictus*, *tessellatus*, *vagus* and *varuna*.

In some cases it has been possible to compare the eggs of the same species from various parts of India.

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THE EGGS OF INDIAN ANOPHELES, WITH DESCRIPTIONS OF THE HITHERTO UNDESCRIBED EGGS OF A NUMBER OF SPECIES.

BY

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AND

P. J. BARRAUD, F.E.S., F.Z.S., F.L.S.

BY using the method described by one of us (Barraud, *Ind. Jour. Med. Res.*, **17,** p. 281, 1929) for sending mosquitoes alive over long distances, we have recently had the unique experience of being able to study at Kasauli, between October and December of this year, eggs laid by gravid females of 23 Indian species of Anopheles, many of which are not otherwise procurable except at a distance of a thousand miles or more.

ACKNOWLEDGMENTS.

We desire to express our obligation to those who have sent us the material to enable us to do this, viz., to Mr. K. Bose, Honorary Secretary, Birnagar Palli Mandali, for many species from Birnagar, Bengal; to Mr. M. D. Engineer, through the Superintendent, Andhra Valley Power Co., for material from the Andhra Valley, Bombay; to Capt. P. M. Conroy, I.M.S., for material from the Malakand in the extreme north-west of India; to Mr. M. O. T. Iyengar for *A. ludlowi* and other species from Budge Budge near Calcutta; to Capt. B. S. Chalam for material from Bengal; to Mr. Anantiswami Rao for material from Mysore State and to Jemadar Harbhagwan for material from the Jeypore Hill Tracts in the north of the Madras

Presidency. Besides the above we have also to thank Dr. G. Macdonald and Assistant Surgeon Abdul Majid of the Malaria Survey of India for their kindness in sending us much material from the Experimental Station at Karnal in the form of eggs on wet filter paper with the corresponding adults and in rearing adults from particular batches of eggs and in other ways.

PREVIOUS WORK ON THE EGGS OF INDIAN ANOPHELES.

Stephens and Christophers (1902*a*) described and figured from Bengal the eggs of *A. rossii*, *A. fuliginosus*, *A. hyrcanus* var. *nigerrimus* and *A. christophersi*. This last species they state had been found by them only in the Duars. In a later paper (1902*b*) they described and figured the eggs of *A. culicifacies*, *A. pulcherrimus*, *A. stephensi*, *A. turkhudi*, *A. maculipalpis* (*A. jamesii* of St. and Ch.) and (unfigured) those of *A. barbirostris* and *A. theobaldi*. From our present work we can say that the eggs figured of *A. rossii* are of that species and not *A. vagus*. The figures of the egg of *A. christophersi* show a long narrow parallel-sided deck about one-eighth the width of the egg including the floats, and floats which do not approach the anterior end of the egg by more than about one-eighth of the length of the egg.

Christophers (1911) later described and figured the egg of *A. listonii* from Amritsar and of *A. maculatus* from Madhupur (Punjab). The figure shows the egg of *A. listonii* with the deck divided into two parts and about one-sixth of the width of the egg including the floats.

Gill (1912) described the egg of *A. lindesaii* from specimens caught at Murree.

Strickland (1915) described and figured the eggs of *A. ludlowi* and, as indicated by the author's descriptions of the adult and larva, those of *A. vagus* (as *A. rossii*). The author notes that the eggs of the two species dealt with very closely resemble each other.

The only eggs of Anopheles since described in India have been those of *A. barianensis* by Christophers (1916) and those of *A. annandalei* var. *interruptus* by Puri (1929).

The eggs of certain other species on the Indian list are known from publications relating to other areas. Foley (1912) has described and figured the eggs of *A. multicolor* from Algeria. The eggs of *A. karwari*, *A. aconitus*, *A. tessellatus* and *A. kochi* have been described by Stanton (1913, 1914, 1922). More recently Theodor (1925) has described the eggs of *A. sergentii* and *A. superpictus* from Palestine. The characters given for these species have been confirmed, as regards *A. tessellatus* by ourselves and as regards *A. sergentii* and *A. superpictus* by Puri (1931), for these species in India.

Patton (1905) has given a description of the egg of *A. dthali* from Arabia, but unless the synonomy now adopted is incorrect Patton's description is not confirmed by us and the description of the egg of *A. dthali* here given is as observed by Puri (1931) at Jandola (S. Waziristan) where the author bred adults of *A. dthali* from eggs having these characters.

Of the 23 species recently studied at Kasauli, 16 have already been described by others, but we have been able to confirm in most cases the characters given and to describe the eggs more fully. In some cases also the actual species to which the description should apply was previously doubtful. The eggs of the remaining 7 species have not been described before, viz., those of *A. jamesii*, *A. jeyporiensis*, *A. moghulensis*, *A. pallidus*. *A. philippinensis* (?), *A. ramsayi* and *A. maculatus* var. *willmori*.

As the characters of the egg of some 30 species, out of a total in all of about 40 species of Indian Anopheles, are now adequately known, we have summarized knowledge regarding these in the present paper, rather than wait to complete the whole list which might not be possible for some time.

The Indian species of which the egg is at present still unknown are, *A. aitkenii*, *A. insulæflorum*, *A. culiciformis*, *A. sintoni*, *A. gigas*, *A. umbrosus*, *A. leucosphyrus* and *A. majidi*. There is some doubt still also regarding the eggs of *A. philippinensis* and *A. minimus* (type and var. *varuna*).

TECHNIQUE.

The technique employed has been as follows Gravid females sent in Barraud's boxes were caught in test tubes and selected specimens confined for oviposition in small lamp globes (those called 'Boy Globes' obtainable in Calcutta, 4 inches by $2\frac{1}{4}$ inches are very suitable) over the upper end of which mosquito netting had been tied and on which in turn had been placed some raisins and a strip of lint, the latter being kept continuously damp. Under the lower end of the globe is placed a suitable receptacle containing water Suitable vessels for this purpose are small straight sided glass dishes, about $1\frac{1}{2}$ inches diameter by $\frac{3}{4}$ inch high, in which is placed floating on the water a small cork ring coated in hard paraffin, the ring being sufficiently large to come on all sides moderately close to the sides of the vessel. The cork ring gives foothold to the Anopheles, which usually lays its eggs within the ring where they are readily examined if necessary in a floating condition direct under the microscope.

For study and drawing some of the eggs are lifted out on a small strip of filter paper which is placed upon a slide and moistened from time to time by means of a pipette. Under these conditions eggs if necessary can be arranged under a low power binocular with a fine needle to give such views as are required under a higher power. For illumination we have found a beam of light from a small point of light lamp most satisfactory.

Though examination on filter paper under good reflected illumination is most generally satisfactory, the floats may be very well shown up with the egg floating and the use of transmitted, or both reflected and transmitted light. It should also be remembered that where the frill is broad it may not be fully spread out unless the egg is floating in water. As a rule, however, where the frill is of moderate width there is not much difference to be observed. The upper edge of the float

not being attached to the egg may also be slightly altered in position depending upon whether the egg is viewed floating or on blotting paper, especially if the latter is allowed to become somewhat dry. The width of the frill seen from above is apt to be misleading and a lateral view may be necessary to give its real breadth which is often more than suspected from a dorsal view.

In counting the float ridges the float terminations (*see* structure of egg) should always be defined first if possible and the ridges, including these, then counted neglecting any subsidiary folds in the float terminations themselves. If an egg be tilted a little towards its side and well and properly illuminated the characters and limits of the float terminations are generally well displayed.

STRUCTURE OF THE ANOPHELES EGG.

The eggs of Anopheles, with rare exceptions, are boat-shaped, converging at either end to a point, with a flattish *dorsal surface* or deck, more or less surrounded and demarcated by a narrow or broad *frill*, and with a more rounded lower or *ventral surface*, that end of the egg corresponding to the head of the larva, *anterior end*, being somewhat stouter and broader than the opposite or *posterior end*. In nearly all cases there is on each side of the egg a delicate transparent ribbed *float*. At the anterior end of the egg, just below the point of the egg and outside the line of the frill, and only visible as a rule by special manipulation of the egg, is the *micropile*.

The dorsal surface.—The dorsal surface as defined above may be broad and flat like a covered in deck to a sea boat, in which case the floats on either side are usually in contact with its borders. When narrower it may either have the floats in contact with its margins, or it may be very like the deck of a whale-back steamer, the floats being in this case separated from the margins of the dorsal surface by a portion of the ventral surface which under these circumstances extends round to the dorsal aspect of the egg.

The dorsal surface may be completely surrounded and delimited by the frill or where the floats are in contact with its margins, portions of the dorsal surface anteriorly and posteriorly only may be bordered by frill, which are thus more or less demarcated from a middle portion of deck bordered by the floats only. This demarcation is frequently the more marked owing to the ends of the frill, where they join or approach the floats, being somewhat turned inwards towards the middle line of the egg and often ending in a free flap-like termination or *tag*. The anterior and posterior *demarcated areas* are thus commonly oval or horse-shoe shaped, whilst the middle portion is more or less the shape of a parallelogram, its sides, however, often being more or less encroached upon by the upper edge of the floats. This upper edge not being fixed, the exact degree to which the middle portion of the dorsal surface is encroached upon is often variable in the same species, especially in those where the float edge is of considerable length and the floats broad. Other characters

are seen in particular species which are described in the body of this paper when describing the egg of the species.

The dorsal surface is rarely ornamented, but in the genus *Anopheles* may be marked with reticular pattern like the ventral surface. In subgenus *Myzomyia* it may in some cases be more or less extensively marked with pale punctate spots. As a rule the dorsal surface is dark and granular with no silvery effect from whichever angle it is viewed.

At either end of the dorsal surface, occupying the pointed extremities of the egg, and just included within the line of the frill as it passes round these, are a number of raised round or oval black nodules or bosses. The number of these may appear to be from 3 to 6, or if carefully examined up to as many as 8, as given by Nicholson (1921). They appear to be of no systematic importance and their number is difficult to ascertain with accuracy. They are of a peculiar character in *A. tessellatus.*

The ventral surface.—This surface is rounded and usually appears finely or coarsely granular with a pig-skin-like punctate effect in certain lights. In certain lights it appears black, but in others shows a silvery effect due to a delicate outer covering membrane readily detached in parts by trauma carrying with it any ornamentation there may be (*exochorion*) and exposing a dark shiny inner coat (*endochorion*). In certain species the ventral surface is ornamented with beautiful polygonal pale or silvery white markings. This seems to be, curiously enough, the only distinguishing point between the eggs in subgenus *Anopheles*, where polygonal markings are present, and subgenus *Myzomyia*, where they are absent, except in the group *Neomyzomyia*, and in one or two peculiar species, which in this respect conform to subgenus *Anopheles.* Occasionally in the egg of *A. listonii* faint indications of polygonal markings may be seen in a good light, but these are without any pale ornamentation.

The frill.—The frill is a delicate membranous expansion arising round the borders of the dorsal surface in the whole or part of their extent. It is usually of an opaque white or silvery appearance and shows transverse striations and a somewhat crenulated edge. At either end of the egg the frill is usually continued round and a little below the actual pointed extremity of the egg, which is thus left enclosed within the area delimited as dorsal surface; the frill is, however, nearly always greatly narrowed down and reduced to a mere line in this situation.

Where the floats do not touch the margins of the dorsal surface the frill is usually continued along the full length of the margin of this surface, though it is sometimes reduced to little more than a white line delimiting the surface. In those eggs where the floats touch the margin of the dorsal surface the frill is very commonly deficient in the region of the floats and present only at either end of the egg. In such cases it may terminate towards the float by appearing to become merged with the inner margin of this. More usually the frill terminates somewhat more abruptly in the form of a little free rounded end or tag as previously mentioned. Even where the

floats are in contact with the margins of the dorsal surface the frill is not uncommonly continued past these uninterruptedly round the deck margin.

The frill especially when very broad may occupy a more or less horizontal position and so appear broad in an upper view of the egg, spoken of in the descriptions as 'laterally extended,' or, more usually, it is directed vertically to the egg surface and so does not appear so broad as it is unless the egg be viewed laterally.

The floats.—These, when full of air in the normal condition, appear as transparent bleb-like ribbed structures on either side of the egg. They are usually of a somewhat flattened hemispherical appearance seen from above, and more or less fusiform, oval, or vermicular in outline seen from the side.

In all species where floats are present these consist of a number of dorso-ventrally arranged convex ridges, *float ridges.* Commonly the membrane of each ridge has a more or less developed rib-like thickening which appears dark by transmitted light but may appear more or less milky white by reflected light. As a rule each ridge broadens out somewhat as it nears the more expanded ventral margin of the float and here one or more short extra ribbed thickenings may be interpolated between each of the main thickenings. Seen from above each ridge forms at the apparent float margin a more or less rounded bulge, or more or less sharp serration, depending on circumstances under which the egg is viewed and the species. Too much stress cannot be laid on such appearances but in some species the floats do appear to be essentially smoother than in others. In some species the rib-like thickenings are so developed as to give a special double contour effect to the ridges.

The float ridges rarely run perfectly straight in their course across the float or even maintain the same curvature throughout. Such deviations are not accidental but due to definite structural features of the float. At either pointed extremity of the float is a short terminal bulla which commonly ends in a somewhat flattened fashion on the egg surface, *float termination.* The next few succeeding ridges curve round the convex unattached margin of the float termination and each other in succession in a more or less regular manner, becoming less sharply curved as they are further from the ends of the float. After two or three such ridges, however, each ridge tends to become somewhat overhanging and its edge increasingly convex at a certain point. These pointed overhanging crests of the ridges are directed towards the middle of the egg and if continued the series of either side would appear bound to come to an abrupt meeting about the middle of the egg. This is, however, usually avoided by the series taking up a dorsal and ventral trend respectively so that they pass each other in the middle portion of the float and then gradually die out. This structural feature is almost always present to some degree but is much more marked in some species than in others probably depending on the width of the float and the need for additional support. One effect produced is that in the outline of the float as viewed from above the middle portion is not quite so convex

as it should be for symmetry if it does not actually show a slight depression in this situation.

Though the floats appear as inflated blebs on the egg surface, they are, as noted by Nicholson (1921), really only attached along their ventral margin where they take origin as a fold, their upper edges being free and merely applied to the egg surface. In *A. aconitus*, where the free edge of the float is unusually long, it is not uncommon to see the float edge separated from the egg and showing like an open purse the portion of egg surface normally hidden by the float.

When eggs are found sunk, probably from being laid in an immature condition or under water, the floats are not filled with air but contain fluid. In such cases the floats appear dark when the egg is placed on filter paper and examined by reflected light. After a time as the egg dries air may enter and the floats resume their normal silvery appearance.

The micropile.—The *micropilar area* is usually seen as a black spot distinguished in certain lights from the rest of the ventral surface of the egg by not giving any silvery sheen. To see it the egg must be suitably arranged in a good light; the micropilar structures are then seen as a shining black slightly raised button-like or pustule-like elevation, sometimes with a central depression, the *micropile.* Round the edges of the micropilar area there may be visible about 8 crescentic scollops, which may show pale markings suggestive of frill structure. In *A. turkhudi* there is a considerable area at the thicker extremity of the egg separated off by a circular scolloped line. Whether this indicates a greatly enlarged micropilar area is not known, but it appears possible it may be. In this case the frill carried at the end of the egg in some Neotropical forms may be a development of the minute frill-like edge sometimes seen round the margins of this area as described above.

CLASSIFICATION OF ANOPHELES EGGS.

Ornamentation of the ventral surface with a pale polygonal network appears to be of significant classificatory value in respect to Indian species so far examined as between subgenus *Anopheles*, where such a network is present, and subgenus *Myzomyia*, where it is absent except in the two representatives described of the group *Neomyzomyia*, which in other respects, e.g., in the pleural hairs of the larva show *Anopheles* affinities.

Apart from such ornamentation of the ventral surface, the eggs examined have not appeared to show any definable structural characters which are not reproduced apparently equally in the two subgenera. The position as regards relation of the structure of the egg to classification of the adult, etc., is shown below. For the sake of completeness eggs described from other areas are given in brackets. An asterisk marks those species in which a polygonal ornamentation of the ventral surface has been noted. Following the statement of classification is a synoptic arrangement of the eggs of Indian species so far as known.

Type of egg.	Anopheles.	Nyssorhynchus.	Myzomyia.				
			Neomyzomyia.	Pseudomyzomyia.	Neocellia.	Myzomyia.	Paramyzomyia.
A. Eggs probably of primitive type with frill-float surrounding egg.	* *barianensis.* * (*plumbeus*) (1) (*barberi*) (2) * (*elutus*) (3) ? (*maculipes*) (12)	..					
B. Eggs with terminal frill ..	(*pseudopunctipennis*) (4)	(*tarsimaculatus*) (5) (*albitarsis*) (5) (*darlingi*) (5)					
C. Whale-back eggs with floats separated from dorsal surface. (Type 1 of Stephens and Christophers.)	* *hyrcanus* * *barbirostris* * (*punctipennis*) (2) * (*crucians*) (2)	..	* *tessellatus* * *kochi*	* (*gambiæ*) (13)	..	*culicifacies* *listoni* *minimus* *aconitus*	
touching margin of dorsal surface. (Christophers.) (*a*) Open boat-shaped: dorsal surface as broad as egg body no ventral surface visible from above. With frill continued round whole margin of dorsal surface.				*subpictus* *vagus* *ludlowi*	*pulcherrimus*	(*tibani*) (*pretoriensis* ?) (15)	(*hispaniola*) (9)
(*b*) Ditto. With frill not continued past floats.	* (*maculipennis*) (6) * (*quadrimaculatus*) (2) (*algeriensis*) (7)				*fuliginosus* *pallidus*	*jeyporiensis*	

D. Various types of boat-like eggs with floats (Types 2 and 3 of Stephens and	(c) More laterally compressed eggs; ventral surface visible from above towards ends of egg. Egg more or less lifeboat shaped with demarcated areas. (*See* text.)	* *annandalei* * *lindesaii* (*bifurcatus*) (8)				*jamesii* *moghulensis* *ramsayi*	*sergentii*	
	(d) Ditto. Egg more or less markedly galleon-shaped. (*See* text.)					*stephensi* *maculipalpis* *maculatus* *theobaldi*		
	(e) Egg probably of this type, but of retrogressive form. With well-developed frill but no floats.			* (*nili*) (14)		*superpictus*	*dthali*	(*multicolor*)
	(f) Ditto. With neither frill nor floats.							*turkhudi* (*italicus*) (10) (*jehafi*) (*cinereus* ?) (15)

The egg of *C. fajardi* (12), * *A. grabhamii* (11), * *A lutzi* (12), *A. argyritarsis* (11) (12) and *A. albimanus* (?) (12) have also been described but their morphology is too uncertain for inclusion in the table. The egg of *A. gambiæ* seems somewhat intermediate between the compartment it has been placed in and the one below since the floats approach very nearly to the fringe and the deck is somewhat narrowed only, an approach to this condition is seen in *A. vagus* where the floats are not actually quite in contact with the frill

(1) Eysell (1912); Edwards (1921); MacGregor (1921); Martini (1929). (2) Howard, Dyar and Knab (1917). (3) Edwards (1921); Theodor (1925); Falleroni (1926). (4) Herms and Freeborn (1920). (5) Root (1926). (6) Grassi (1901); Howard (1901); Nuttall and Shipley (1901); MacGregor (1921); Falleroni (1926). (7) Sergent (1903); La Face (1929). (8) Martini (1920); MacGregor (1921); Martini (1929). (9) Sergent (1910). (10) Raffaele (1928). (11) Goeldi (1905). (12) Peryassu (1908). (13) Annett, Dutton and Elliott (1900). (14) Theobald (1910). (15) Patton (1905).

SYNOPTIC ARRANGEMENT OF KNOWN EGGS OF INDIAN ANOPHELES.

1.	**Ventral surface with pale polygonal markings**	2.
	Ventral surface not so ornamented	6.
2.	**Floats absent, dorsal surface of egg quadrilateral in shape**	*A. barianensis.*
	Floats present, upper surface of egg not so	3.
3.	**Floats touching margin of dorsal surface**	4.
	Floats not touching margin of dorsal surface	5.
4.	**Floats sharply tapering to points at the ends; both portions of frill together not above $\frac{1}{8}$ of the length of the egg**	*A. annandalei.*
	Floats ending in large rounded float termination; both portions of frill together exceeding $\frac{1}{8}$ of the length of the egg	*A. lindesayi.*
5.	**Dorsal surface distinctly narrower than portion of ventral surface between this and float; frill narrow; float ridges 30 or over, narrow, regular**	*A. hyrcanus* var. *nigerrimus.* *A. barbirostris.*
	Dorsal surface about same width as portion of ventral surface between this and float; frill seen laterally about half breadth of dorsal surface; float ridges not exceeding 20, broad, with sharp serrated contour	*A. tessellatus.*
6.	**Floats absent**	7.
	Floats present	9.
7.	**Frill rudimentary, seen as small oval tache on egg**	*A. turkhudi.*
	Frill well developed	8.
8.	**Frill present only at ends of egg**	*A. multicolor.*
	Frill continuous round margin of dorsal surface	*A. superpictus.* *A. dthali.*
9.	**Floats separated from margin of dorsal surface**	10.
	Floats touching margin of dorsal surface (or separated only by a very small interval)	12.
10.	**Frill well developed in middle portion of egg; about $\frac{1}{8}$ depth of egg seen laterally**	*A. culicifacies.*
	Frill either discontinuous in middle or very narrow, distinctly less in middle of egg than $\frac{1}{8}$ depth of egg	11.
11.	**Terminations of floats not approaching extremities of egg within $\frac{1}{8}$ of egg length or more; float ridges seen from above markedly longer than broad**	*A. listonii.*
	Terminations of floats approaching extremities of egg by 1-12 of the egg length or less; float ridges seen from above almost as broad as long	*A. aconitus.*
12.	**Frill continued along whole margin of dorsal surface and passing above floats**	13.
	Frill interrupted in middle of egg where floats are present	16.
13.	**Frill striated through whole extent**	14.
	Frill striated in terminal portions only	15.
14.	**Frill a quarter width of egg body; float ridges 30–40**	*A. subpictus.*
	Frill distinctly less than a quarter width of egg body; float ridges 20–30	*A. vagus.*
15.	**Dorsal surface with punctæ confined to margins; float ridges about 20; egg rather deep and somewhat concave above**	*A. ludlowi* var. *sundaicus*
	Dorsal surface with punctæ in the form of white spots covering whole extent; float ridges about 16; egg very flat and shallow with flat dorsal surface	*A. pulcherrimus.*

16. **Dorsal surface as wide as egg body, no portion of ventral surface seen when egg is viewed from above 17**
Dorsal surface not so, at least some ventral surface visible towards ends of egg when viewed from above .. .. 18.

17. **Frill merging gradually at float junction .. .. .. *A. fuliginosus.* *A. pallidus.***
Frill with more or less tags at junction with float .. .. *A. jeyporiensis.*

18. **Anterior demarcated portion of dorsal surface twice or nearly twice as long as posterior; floats extending distinctly nearer to narrow end of egg .. .. 19.**
Anterior demarcated portion of dorsal surface only slightly longer than posterior; floats extending to about an equal distance from either end of the egg .. .. 22.

19. **Floats about half the egg length; float ridges about 12 .. *A. ramsayi.***
Floats distinctly more than half egg length; float ridges over 16 .. .. .. 20.

20. **Middle portion of dorsal surface at least equal to the anterior and posterior demarcated portions taken together; floats occupying somewhat less than $\frac{3}{4}$ lateral aspect of egg in middle portions; frill somewhat narrower .. .. .. *A. jamesii.***
Middle portion of dorsal surface less than the anterior and posterior demarcated areas taken together; floats very broad occupying $\frac{3}{4}$ of the lateral aspect of the egg in middle portion; frill somewhat broader .. .. *A. moghulensis.*

21. **Anterior demarcated area obviously shorter than the middle area, say $\frac{3}{4}$ of this; egg flattened, not galleon-shaped .. .. *A. sergentii.***
Anterior demarcated area about as long as middle area; egg galleon-shaped .. .. 22.

22. **Floats not markedly concave above .. .. 23.**
Floats markedly concave above .. .. .. *A. maculatus.* *A. maculatus* var. *willmori.*

23. **Float ridges about 14; frill less than 1-10 depth of egg, floats only slightly more than one-third the egg length .. .. *A. stephensi.***
Float ridges about 22, frill about 1–10 depth of egg; floats distinctly longer than one-third the egg length .. .. .. *A. maculipalpis* var. *indiensis.*

Descriptions of the Eggs of Indian Anopheles.

Subgenus ANOPHELES.

A. aitkenii James, 1903.

Egg unknown.

A. insulæflorum Swellengrebel, 1920.

Egg unknown.

A. culiciformis Cogill, 1903.

Egg unknown.

A. sintoni Puri, 1929.

Egg unknown.

A. barianensis James, 1911.

The egg has been described and figured (photograph) by Christophers (1916).

Length 0·47 mm., greatest breadth including frill 0·21 mm., lozenge-shaped or bifusiform with conical ends. *Dorsal surface* slightly convex, completely separated from the ventral surface by the frill; unornamented. *Ventral surface* more convex than the dorsal; ornamented with silvery polygonal markings. *Floats* absent. *Frill* very broad, reaching about one-quarter of the width of the egg body, continuous round the whole egg including the ends, laterally extended and more or less horizontal, of a distinct thickness with rounded edge and marked throughout whole extent with transverse groove-like markings, coarser internally than externally.

Resembles in general characters the egg of *A. plumbeus* Stephens but judging from the drawings of Eysell (1912) and of Edwards (1921) and others possibly slightly broader and more quadrangular in outline.

A. annandalei Baini Prasad, 1918

The egg of var. *interruptus* has been described and figured by Puri (1929).

Length about 0·45 mm., greatest breadth including floats 0·16 mm., of the usual boat shape, rather long and narrow. *Dorsal surface* moderately broad, about half the width of the egg body, slightly granular and marked with polygonal areas. *Ventral surface* dark grey showing a reticular pattern as on the upper surface. *Floats* touching the margin of the dorsal surface, extending nearly from end to end of the egg, nearly as broad in a large part of their extent as the lateral aspect of the egg, but narrowing sharply to fine points at the ends. Float terminations small, float ridges about 25 in number. *Frill* narrow, restricted to the two ends of the egg where the floats do not extend, striated; the total length of frill at the two ends of the egg on each side taken together less than one-quarter the total egg length.

In general characters resembles the egg of *A. lindesaii*.

A. lindesaii Giles, 1900.

The egg has been described by Gill (1912). A description of the egg of the type form (from Kasauli) is given below (*vide* Plate I, fig. 1).

Length 0·50 mm., greatest breadth including the floats 0·17 mm., of the usual boat shape, rather long and narrow. *Dorsal surface* with an anterior and posterior demarcated area, about equal in length and each about a sixth of the egg length and as broad as about a quarter of the greatest breadth of the egg, the middle portion three or four times as long as either end portion and variable in width depending on encroachment by the floats which may in some cases meet for a portion of their length in the middle line; black, granular, unornamented. *Ventral surface* ornamented with pale polygonal network. *Floats* touching the margin of the dorsal surface throughout nearly their whole length, very long and broad, occupying

about the middle two-thirds (0·68) of the total egg length, elongate oval in lateral view with flattened upper border and occupying in their middle portion about the dorsal three-quarters of the lateral aspect of the egg. Float terminations very large, flat, rounded ; float ridges about 20. *Frill* narrow, directed upwards. restricted to the two ends of the egg where the floats do not extend and ending usually in small tags at the float junction, striated ; the total length on each side of the two portions of frill taken together one-third or more of the total egg length.

A. gigas Giles, 1901.

Egg unknown.

A. hyrcanus var. **nigerrimus** Giles, 1900.

The following description applies to the eggs of this form from Birnagar (Bengal) and Karnal (Punjab) (*vide* Plate I, figs. 2 and 3).

Length 0·50 mm., greatest breadth including floats 0·19 mm., of the usual boat shape, rather flat and broad. *Dorsal surface* extremely narrow, slit-like, straight except for the two ends which are expanded in a circular manner, extending from end to end of the egg ; black, granular, unornamented. *Ventral surface* ornamented above and below with network of pale polygonal markings. *Floats* not touching margin of dorsal surface, long, occupying about the middle two-thirds (0·68) of the egg length, extending to about an equal distance of either end of the egg, elongate oval or fusiform in lateral view, somewhat concave dorsally, moderately broad, occupying about half the width of the lateral aspect of the egg in their middle portion. Float terminations small, crescentic ; float ridges about 30 to 35, narrow, very regular and smooth. *Frill* very narrow, reduced practically to narrow white line, striated, extending all round margin of dorsal surface

The narrow slit-like character of the dorsal surface of the egg of *A. hyrcanus* var. *nigerrimus* never appears to vary to any extent and the drawing given by Edwards (1921) of the egg of the European *A. hyrcanus* with a rather broad expanded deck, nearly as broad anteriorly as the egg body would seem to point to this being quite a distinct egg.

A. barbirostris Van der Wulp, 1884.

Difficulty was found in getting this species to lay and the material being scanty we have examined the eggs only of one specimen which had sunk to the bottom (*vide* Plate V, fig. 32).

Resembles very closely the egg of *A. hyrcanus* var. *nigerrimus*. The only differences noted were that the dorsal surface was slightly broader and the floats possibly slightly longer (0·75 of egg length).

A. umbrosus Theo., 1903.

Egg unknown.

Subgenus MYZOMYIA.

Group Neomyzomyia.

A. tessellatus Theo., 1901.

The egg of *A. tessellatus* has been described from the Federated Malay States by Stanton (1913). Identical characters were shown by eggs laid by *A. tessellatus* from western India (Andhra Valley) (*vide* Plate I, figs. 4 and 5).

Length 0·50 mm., greatest breadth including floats 0·18 mm., of the usual boat shape, but of peculiar form (*see* figure). *Dorsal surface* narrow, about one-quarter as broad as the greatest width of the egg and about equal to the extent of ventral surface when looked down upon between it and the float, straight, with parallel sides, passing from end to end of the egg, very level or even slightly convex antero-posteriorly ; black, granular, unornamented ; the bosses at the ends of the egg very conspicuous, since unlike those in other Anopheles so far seen they are clear and light coloured. *Ventral surface* ornamented above and below with pale polygonal markings. *Floats* not touching margins of dorsal surface, long, narrow, occupying slightly less than the middle two-thirds (0·62) of the egg length, extending to within about an equal distance from either end, elongate fusiform (vermicular) in lateral view, situated rather low down on the lateral surface, occupying less than half the lateral aspect of the egg in their middle portion. Float terminations of moderate size, more or less rounded in outline ; float ridges about 18 in number, very short and deeply indented with well marked crest, giving an unusual, 'serrated' outline to floats when viewed from above. *Frill* fairly broad, about $\frac{1}{8}$ depth of egg when seen from the side, erect and not extended laterally, present all round margin of dorsal surface except at the extremities of the egg and markedly striated in full extent.

A. kochi Donitz, 1901.

The egg of this species has not been seen by us, but is described by Stanton (1914) whose description is given below :—

The upper surface is narrow, slightly expanded at either end, and the floats do not touch its margin. The narrow striated frill is continuous around the whole of the margin of the upper surface. The thin silvery membrane which covers the under surface of the ovum and the lateral areas between the floats and the frill, has a reticulated pattern. The floats are oblong in shape and extend over the middle two-thirds of the ovum's length ; each float has about 20 corrugations. Length of ovum 0·45 mm., greatest breadth 0·16 mm. This ovum does not differ in any detail from that of *A. tessellatus* (Bull. Ent. Res., IV, p. 131).

A. leucosphyrus Donitz, 1901.

Egg unknown.

Group Pseudomyzomyia.

A. subpictus Grassi 1899.

As described and figured by Stephens and Christophers (1902*a* and *b*) (*vide* Plate III, figs. 14 and 15).

Length 0·66 mm., greatest breadth including floats 0·21 mm., of the usual boat shape, but very broad, oval, flat and shallow. *Dorsal surface* wide, as wide throughout as the egg body, the middle portion not perceptibly narrowed or only very slightly so, without specially demarcated areas, covered throughout with pale punctæ. *Ventral surface* with or without pale punctæ.* *Floats* touching, or nearly touching, margin of dorsal surface, rather long, occupying about the middle two-thirds of the egg length (0·6), extending to about an equal distance from the narrower and broader end of the egg or slightly nearer one or the other, oval in lateral view, rather broad and occupying more than the dorsal half of the lateral aspect of the egg. Float terminations relatively small, rounded, flattened; float ridges 30 to 40, narrow, regular, rather smooth. *Frill* very broad, stiff, extending laterally, continued all round the margin of the dorsal surface except at the ends and coarsely striated throughout whole extent, rather thick and slightly opaque or milky; when fully displayed almost a third of the width of the deck.

A. vagus Donitz, 1902.

The egg of *A. vagus* has been described as that of *A. rossii* by Strickland (1915). The following is a revised description based on material from Bengal (*vide* Plate III, fig. 16).

Length 0·49 mm., greatest breadth including floats 0·16 mm., of the usual boat shape, somewhat shallow and flat. *Dorsal surface* wide, as wide throughout as the egg body, the middle portion not perceptibly narrowed or very slightly so, without specially demarcated areas; ornamentation not recorded. *Ventral surface* without polygonal markings. *Floats* nearly touching margin of dorsal surface, of moderate size, occupying about the middle half of the egg length, extending to about the same distance from the narrower as from the broader end or slightly nearer the latter, oval in lateral view, somewhat broad, occupying rather more than the dorsal half of the lateral aspect of the egg. Float terminations of moderate size, rounded; float ridges 20 to 30, somewhat narrow. *Frill* striated, moderately broad, continued round margin of dorsal surface except at ends and passing over the floats where it appears also striated; narrower and more transparent than in *A. subpictus*.

A. ludlowii var. **sundaicus** Rodenwaldt, 1926.

The egg of *A. ludlowii* from F. M. S. has been described by Strickland (1915). The following is a revised description based on material from Budge Budge, near

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* There seems to be some variation in this respect possibly depending on the extent to which the white appearance of the spots is developed. The same applies to *A. ludlowi*.

Calcutta, where Mr. M. O. T. Iyengar has recently found this species (*vide* Plate III, fig. 17).

Length 0·44 mm., greatest breadth including floats 0·16 mm., of the usual boat shape, somewhat broad and flat and rather concave above antero-posteriorly. *Dorsal surface* wide, as wide as the egg body, the middle portion slightly narrowed, without specially demarcated areas, with scattered pale punctæ along the lateral margins. *Ventral surface* with punctæ but somewhat inconspicuous in examples seen. *Floats* touching margins of dorsal surface, moderately long, occupying somewhat more than the middle half, or approaching two-thirds of the egg length, about equally distant from either end of the egg, fusiform in lateral view and slightly concave above, occupying about the dorsal half of the lateral aspect of the egg. Float terminations of moderate size, rounded ; float ridges about 20. *Frill* broad, extending laterally and reaching about the width of the floats when fully displayed, continued round margin of dorsal surface except at ends and passing over floats, definitely striated, however, only where these structures do not extend. The unstriated or poorly striated portion appears less rigid than the stiff striated portion.

The egg, as noted by Strickland, resembles that of *A. vagus*. It is distinguished, however, by the somewhat longer floats and the unstriated middle portion of the frill. The scattered punctæ along the lateral borders of the dorsal surface also appear very characteristic and may offer a further distinguishing character.

Group Neocellia.

A. superpictus Grassi, 1899.*

Dr. Puri informs us that the characters given by Theodor (1925) for *A. superpictus* in Palestine have been confirmed by him for this species on the north-west of India.

The egg is of the normal boat shape. The *upper surface* as broad as the egg body and the middle area slightly if at all narrowed, ornamented with irregular reticulation. The *ventral surface* unornamented. *Floats* entirely absent. *Frill* very broad, nearly as broad as half the width of the upper surface or as depth of the egg in side view, continued all round the margin of the upper surface and striated through its whole extent ; normally mainly erect but capable of lateral extension.

A. moghulensis Christophers, 1924.†

From Andhra Valley (West Coast) (*vide* Plate III, fig. 18).

Length 0·41 mm., greatest breadth including floats 0·16 mm., of the usual boat shape, rather compressed laterally. *Dorsal surface* somewhat less broad at

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* According to Puri (*Ind. Med. Res. Mem.*, No. 22, 1931) this species, on larval characters, shows *Neocellia* affinities.

† This species is considered to belong to the group *Neocellia* on larval characters by Puri, *Ind. Jour. Med. Res.*, **16**, p. 513, 1928.

ends than the egg body, with an anterior and posterior demarcated area, the former about twice as long and considerably broader than the latter ; the middle portion markedly narrowed by encroachment of floats which may nearly meet in the middle line. *Ventral surface* unornamented. *Floats* touching margin of dorsal surface long, occupying somewhat less than the middle two-thirds (0·6) of the egg length, extending nearer to the narrower than to the broader end of the egg ; oval in lateral view, very broad, occupying in a considerable part of their extent about three-quarters of the lateral aspect of the egg, upper surface not concave. Float terminations large, rounded ; float ridges 17 to 20, long, rather crested and waved, those towards the ends of the float running in wide sweeps round the float terminations. *Frill* rather narrow, 1-10 or less of depth of egg, not extending laterally, striated, ending in tags or merging into floats at terminations ; the frills of each side taken together about equal to half the length of the egg.

A. fuliginosus Giles, 1900.

From numerous localities including Chakdara, N. W. F. Province, and Bengal. As described by Stephens and Christophers (1902*a*) (*vide* Plate IV, figs. 20 and 21).

Length 0·50 mm., greatest breadth including floats 0·18 mm., of the usual boat shape, rather flat and shallow. *Dorsal surface* as broad as egg body, without distinct demarcated areas, only slightly narrowed in middle portion, the portion delimited by frill anteriorly somewhat longer and broader than that so delimited posteriorly ; dark granular unornamented. *Ventral surface* unornamented. *Floats* touching margin of dorsal surface, of moderate length, occupying somewhat more than the middle half (0·56) of the egg length, extending very slightly nearer the narrower than the broader extremity of the egg ; oval in lateral view, very slightly if at all concave above, occupying in their middle portion the dorsal half or somewhat more of the lateral aspect of the egg Float terminations of moderate size ; float ridges about 20, rather smooth and regular but showing curvings. *Frill* moderately broad, somewhat extended laterally, about $\frac{1}{8}$ depth or breadth of egg, merging gradually into floats at junction with these ; the two lengths of frill on each side taken together equalling more than half the egg length.

A. pallidus Theo., 1901.

Differing from the egg of *A. fuliginosus* only in that the floats are noticeably very smooth and the float ridges possibly slightly broader with the number not exceeding 18.

A. philippinensis Ludlow, 1902.

Only the eggs of two specimens thought to be this species have been available for study. The first eggs were laid by a specimen taken to be *A. philippinensis* from Birnagar at Karnal, but were sent to Kasauli unaccompanied by the adult (this being in the early part of our observations). The eggs resembled those of *A. fuliginosus* but the floats were longer (0·7 of egg length) and the two portions of the frill distinctly shorter than half the egg length. The second batch of eggs were

laid at Kasauli by a specimen which is considered to be *A. philippinensis* sent from Budge Budge, but which after egg laying was rather badly rubbed and not very suitable for a careful identification. In this case the eggs resembled those of *A. maculatus* so closely that they appear indistinguishable except for their smaller size. As this specimen was clearly not *A. maculatus*, nor were any specimens of *maculatus* being dealt with at the time a mistake is not very likely. The results regarding the egg of *A. philippinensis* are merely recorded provisionally.

A. jamesii Theo., 1901.

Specimens from Andhra Valley, West Coast (*vide* Plate IV, fig. 24).

Length 0·44 mm., greatest breadth including floats 0·17 mm., of the usual boat shape, rather flat and broad. *Dorsal surface* broad, approaching that of egg body, with anterior and posterior demarcated areas, the former somewhat longer and slightly broader than the latter, either portion about half or somewhat less than the greatest breadth of the egg, the middle portion about the same, this part longer than the two end portions taken together. *Ventral surface* unornamented. *Floats* well developed occupying somewhat less than the middle two-thirds of the egg (0·62), extending a little nearer the narrower than the broader extremity of the egg, oval viewed laterally, somewhat broad occupying somewhat more than the dorsal half of the lateral aspect. Float terminations large, flattened, rounded; float ridges 15 to 17. *Frill* narrow, ending usually in tags at junction with float, less than 1-10 depth of egg, the two portions on each side together about equal to half the egg length.

A. ramsayi Covell, 1927.

Specimens from Birnagar, Bengal (*vide* Plate IV, fig. 23).

Length 0·41 mm., greatest breadth including floats 0·15 mm., of the usual boat shape, rather flat and broad. *Dorsal surface* approaching breadth of egg body. with anterior and posterior demarcated areas, the former about half again as long and distinctly broader than the latter and about as wide as half the greatest breadth of the egg, the middle portion about the same width as the end portions somewhat shorter in length than these two taken together *Ventral surface* unornamented. *Floats* touching margin of dorsal surface, occupying about the middle half of the egg length, extending distinctly nearer the narrower than the broader extremity of the egg, oval in lateral view and occupying about the dorsal half of the lateral aspect of the egg. Float terminations large, flattened, rounded; float ridges few in number, 11 to 13, rather broad. *Frill* striated, narrow, not above 1-10 egg depth seen laterally, ending as a rule in tags at junction with the float; the two portions of frill on each side taken together equal to about half the egg length.

A. maculipalpis var. **indiensis** Theo., 1903.

As described by Stephens and Christophers (1902*b*) (as *A. jamesii*) (*vide* Plate V, fig. 26).

Length 0·53 mm., greatest breadth including floats 0·18 mm., of the usual boat shape, compressed laterally, narrow and high standing with upper surface concave antero-posteriorly (rather like the old galleon). *Dorsal surface* with anterior and posterior demarcated areas, the anterior only slightly longer and about the same width as the posterior, the width of either about one-third the greatest width of the egg, the middle portion about the same length or only a little longer than the anterior demarcated area and about the same width. *Ventral surface* unornamented. Floats touching margin of dorsal surface, occupying about the middle half of the egg length, extending slightly nearer the narrower than the broader extremity of the egg ; oval in general outline seen laterally, not markedly concave above, rather broad and occupying more than the dorsal half of the lateral aspect of the egg in their middle portion. Float terminations moderately large, rounded ; float ridges about 20, rather narrow. *Frill* moderately broad, about $\frac{1}{8}$ the depth of the egg viewed from the side, not extended laterally, striated, ending in marked tags at junction with floats ; the two portions of frill on each side taken together about two-thirds the egg length.

A. stephensi Liston, 1901.

As described by Stephens and Christophers (1902*b*) (*vide* Plate IV, fig. 25).

Length 0·51 mm., greatest breadth including floats 0·19 mm., of the usual boat shape, rather narrow, laterally compressed and high standing with the upper surface markedly concave antero-posteriorly (galleon-shaped). *Dorsal surface* with anterior and posterior demarcated areas, the posterior only very slightly shorter and narrower than the anterior and either about a third as wide as the greatest width of the egg ; the median portion somewhat longer than the anterior demarcated area, of variable width ; dark, granular, unornamented. *Ventral surface* unornamented. *Floats* touching the margin of the dorsal surface, short, occupying about the middle half, or somewhat less than the middle half, of the egg length, extending only very slightly nearer the narrower than the broader extremity of the egg ; oval in lateral view, only very slightly convex if at all dorsally, occupying rather more than the dorsal half of the lateral aspect of the egg in their middle portion. Float termination large, rounded ; float ridges about 15, rather regular and smooth. *Frill* moderately narrow, less than $\frac{1}{8}$ depth of egg, not extended laterally and ending by tags or merging into the float junction ; the anterior and posterior portions of frill of approximately equal length and taken together on each side exceeding half the length of the egg.

Resembling very much the egg of *A. maculipalpis* var. *indiensis* but with the dorsal surface broader and less numerous and broader float ridges.

A. maculatus Theo., 1901.

Specimens from Chakdara, N. W. F. Province. As described by Christophers (1911) for specimen from Madhopur (Punjab) (*vide* Plate V, fig. 27).

Length 0·51 mm., greatest breadth including floats 0·16 mm., of usual boat shape, narrow, laterally compressed, high standing with the upper surface markedly concave antero-posteriorly (galleon-shaped). *Dorsal surface* moderately broad with anterior and posterior demarcated areas, which are commonly completely separated from the middle portion giving three deck areas, the outer two with complete frill, or may be marked off by a constriction at the inner end of one or the other only or neither; the anterior area longer and somewhat broader than the posterior, about a third as broad as the greatest width of the egg: the middle portion about the same breadth and not much, if any, longer than the end portions; dark, granular unornamented. *Ventral surface* unornamented. *Floats* touching margin of dorsal surface, short, narrow, roll-like, occupying scarcely more than the middle third (0·38) of the egg length, extending very slightly nearer to the narrower than to the broader end of the egg; more or less sausage shape in lateral view, the upper border markedly concave, not occupying much more than the dorsal half of the lateral aspect of the egg. Float terminations moderately large, rounded; float ridges about 15 to 16. *Frill* moderately broad, about equal to $\frac{1}{8}$ of the egg depth, not extended laterally, completely encircling the two deck surfaces, or ending in marked tags when these surfaces are open, striated throughout; the two frills of each side when the surfaces are open together equal to half the length of the egg.

A. maculatus var. **willmori** James, 1903.

Indistinguishable from the egg of *A. maculatus*, except that possibly the deck and frill are each somewhat broader (*vide* Plate V, figs. 28 and 29).

A. theobaldi Giles 1901.

Stephens and Christophers (1902*b*) say of this egg, 'Fully developed ova removed from a bred specimen showed, however, that the ovum resembled that of *A. jamesii* (i.e., *A. maculipalpis*). The floats were rather short and situated far forwards as in *A. stephensi*. The fringe is fairly developed but does not pass over the floats.'

A. karwari James, 1903.

According to Stanton (1922) precisely similar to that of *A. maculatus*.

A. majidi McCombie Young and Majid, 1928.

Egg unknown.

A. pulcherrimus Theo., 1901.

As described and figured by Stephens and Christophers (1902*b*) (*vide* Plate I, fig. 6).

Length 0·59 mm., greatest breadth including floats 0·18 mm., of the usual boat shape, but very flat and shallow, the shallowest of all the eggs observed. *Dorsal surface* wide, as wide as the egg body, the middle portion not perceptibly narrowed, without specially demarcated areas, covered throughout with small pale punctæ.

Ventral surface unornamented. *Floats* touching margin of dorsal surface, short, occupying only about the middle third of the egg length, distinctly nearer the narrower than the broader end of the egg ; oval in lateral view, flat above, occupying in their middle portion only the dorsal half of the lateral aspect of the egg. Float terminations moderately large, crescentic ; float ridges about 16, rather regular and smooth. *Frill* broad, at its widest part about a quarter the width of the egg body, notably broader towards the anterior extremity, extended laterally, continued round the margin of the dorsal surface and lying over the floats where, however, it is somewhat narrow and transparent, striated only in front and behind the floats.

As the figure here given was drawn from an egg on filter paper the frill may actually be somewhat broader than shown when seen fully displayed. The reproduction in Edwards (1921) of the figure by Stephens and Christophers is incorrect as regards the frill in that this does not cease at the floats as shown, but is continued over these as shown in the original drawing.

Group Myzomyia.

A. dthali Patton, 1905.

The egg of *A. dthali* as described by Patton (1905) has characters somewhat resembling those of *A. sergentii*. The following description is that observed by Puri (1931) for the species in N. W. India, where this author bred adults of the species from eggs having these characters.

Egg resembles in general characters that of *A. superpictus. Dorsal surface* broad, approximating in width to that of egg body. *Ventral surface* unornamented. *Floats* absent. *Frill* broad, about one-quarter width of dorsal surface, extending all round the margin of the dorsal surface except at the extremities of the egg and striated in its full extent.

The figure of the egg shell given (Plate V, fig. 31) is from a drawing made by one of us (S. R. C.) some time ago, probably from material from Dr. Puri.

A. sergentii Theobald, 1907.

The egg has been figured by Theodor (1925) from Palestine. The characters given by Theodor have been confirmed by Puri (1931) for the species in N. W. India. where the author bred adults of the species from eggs having these characters.

Egg of the usual boat shape (very like the egg of *A. ramsayi*). *Dorsal surface* moderately broad, with demarcated areas anteriorly and posteriorly, the anterior approximately the same length and width as the posterior, each about a quarter the length of the egg ; the median portion at least twice the length of either and as broad or broader. *Ventral surface* unornamented. *Floats* touching margin of dorsal surface, rather long, occupying about the middle two-thirds of the egg length, extending to about an equal distance from either end of the egg ; fusiform in lateral view, slightly concave above. Float terminations rather large, rounded ; float

ridges few in number (13 to 15, figured). *Frill* narrow, confined to portions of the egg where the floats are not present, striated, ending at junction with floats in well-marked tags ; the lengths of frill on each side taken together equal to about half the length of the egg.

A. culicifacies Giles, 1901.

As described and figured by Stephens and Christophers (1902*b*) (*vide* Plate II, fig. 7).

Length 0·45 mm., greatest breadth including floats 0·16 mm., of the usual boat shape, rather short and stumpy. *Dorsal surface* moderately broad, somewhat less than one-third the greatest width of the egg, distinctly broader than the area of ventral surface lying between it and the float, extending the whole length of the egg, elongate oval, or slightly hour-glass or pessary shaped, a little broader than elsewhere at the thicker end of the egg ; dark, granular, unornamented. *Ventral surface* unornamented. *Floats* not touching edge of dorsal surface, occupying a little less than the middle two-thirds of the egg length, extending to about an equal distance from the two ends of the egg ; fusiform in lateral view, rather narrow and occupying rather less than half the lateral aspect of the egg, situated comparatively centrally. Float terminations rather large, rounded, somewhat flattened ; float ridges 15 to 18, moderately smooth and regular without very prominent development of crests as in *A. listonii*. *Frill* moderately broad, viewed laterally about $\frac{1}{6}$ to $\frac{1}{8}$ depth of egg, extending at about an equal width all round margin of dorsal surface except at the ends of the egg and striated throughout.

A. listonii Liston, 1901.

The egg of *A. listonii* as shown by specimens from Karnal and Chakdara is as described and figured by Christophers (1911). Most commonly the two separate decks are as figured by this author, but these may be linked up forming a single elongate oval or hour-glass deck extending the whole length of the egg. The two conditions are commonly seen in the eggs from the same female (*vide* Plate II, figs. 8, 9 and 10).

Length 0·43 mm., greatest breadth including floats 0·17 mm., of the usual boat shape, rather oval, short and broad. *Dorsal surface* usually divided into two oval portions each with a complete circle of frill separated by an area of the egg surface with glistening surface and no middle area of deck as in some species with markedly demarcated ends to the dorsal surface ; the oval areas or corresponding portions of the deck when continuous about as wide as a quarter of the greatest breadth of the egg, broader or at least as broad as the portion of the ventral surface between the dorsal surface and the float ; dark, granular, unornamented. *Ventral surface* unornamented, but in a good light raised outlines of polygonal areas may sometimes be seen, though without pale ornamentation. *Floats* not touching margin of upper surface, long, occupying about the middle three-quarters of the egg length but at least $\frac{1}{8}$ of the egg length intervening between the nearest approach

of the termination of the float to the extremity of the egg; fusiformly oval seen laterally with blunt points, occupying about the middle of the lateral aspect of the egg. Float terminations moderately large and not markedly elongate; float ridges about 19–22, very well developed, somewhat crowded together, with marked double contoured crests and sinuous or contorted course. *Frill* narrow, and where it extends for the full length of the egg reduced almost to a line in its middle portion, less than $\frac{1}{10}$ of the egg depth seen laterally, striated.

A. aconitus Donitz, 1902.

Eggs laid by specimens from Birnagar, Budge Budge and elsewhere in Bengal and from Jeypore, Jeypore Hill Tracts, show the characters described below. The egg is clearly a quite different egg from that of *A. listonii*.

Length 0·44 mm., greatest breadth including floats 0·18 mm., of the usual boat shape, rather broad and flat with concave upper aspect. *Dorsal surface* narrow, slit-like, straight with parallel sides except at extremities where it is somewhat expanded, passing from end to end of the egg; dark, granular, unornamented. *Ventral surface* unornamented. occasionally showing a few traces of polygonal markings but without any pale ornamentation. *Floats* not touching margins of dorsal surface, very long, nearly as long as the egg (0·80), the ends approaching very nearly to the extremity of the egg leaving only about $\frac{1}{12}$ of the length of the egg between. Float terminations long, narrow, usually with indefinite extra ridges; float ridges 18–22, very wide antero-posteriorly, almost as wide as the width of the float seen from above giving a very characteristic 'cellular' effect; ridges with well marked double contour crests, but less contorted than in *A. listonii*. *Frill* very narrow, little more than a line in the greater part of its extent, striated.

A. minimus Theo., 1901.

We are unable to say with certainty what are the characters of the egg in *A. minimus* type or var. *varuna*. Of 19 *A. minimus* group from Bengal of which the eggs and adults have been available all but two laid eggs of the kind described as those of *A. aconitus*. Most of these specimens appear to be *A. aconitus* and they may all be so. Unfortunately both the females which laid eggs resembling those of *A. listonii* are so damaged from wetting that it cannot be said that they are not this species. It is, however, suspected that they may be *A. minimus*. The characters given by Stephens and Christophers for *A. christophersi* from the Duars are like those mentioned above as possibly *A. listonii* but the dorsal surface in both cases seems narrower. It is useless at this stage to discuss the matter until more material has been dealt with. Plate II, fig. 11, shows the characters referred to above.

A. jeyporiensis James, 1902.

Eggs laid by specimens from Jeypore, Jeypore Hill Tracts (type locality), Andhra Valley (West Coast) and Mysore (South India) show the characters described

below, adults showing the type characters have also been reared from these eggs at Karnal (*vide* Plate III, fig. 19).

Length 0·46 mm., greatest breadth including floats 0·17 mm., of the usual boat shape, rather flat and shallow. *Dorsal surface* of the full width of the egg body, somewhat convex laterally, only slightly narrowed in the middle portion, the portion delimited by frill anteriorly distinctly broader and longer than that so delimited posteriorly ; dark, granular, unornamented. *Ventral surface* unornamented. *Floats* touching edge of dorsal surface, of moderate length, occupying about the middle half, or slightly more than the middle half, of the egg length, extending nearer to the narrower than to the broader end of the egg ; fusiform viewed laterally, the upper border not concave, rather broad, occupying rather more than the dorsal half of the lateral aspect of the egg in its middle portion. Float terminations moderately large, rounded ; float ridges 13–17. *Frill* moderately broad, about $\frac{1}{8}$ depth or breadth of egg, directed somewhat laterally, striated, ending in more or less distinct tags at junction with the floats ; taken together on each side somewhat more than half the egg length.

A. **turkhudi** Liston, 1901.*

The following is the description given by Stephens and Christophers (1902*b*).

'The chief characters of the ovum are :

(1) No separation of an upper surface as in all other Anopheles ova. At the thicker end of the ovum there is an oval area about a quarter the length of the whole egg. This is glistening white and striated, and probably represents the upper surface of other Anopheles ova.

(2) There are no floats or any markings representing them.

(3) There is a pale area at the thicker end of the egg with a scalloped edge.

(4) The ovum is otherwise without markings.'

The figure accompanying this paper is from drawings made by one of us (S. R. C.) in June 1921 from ova laid by a specimen taken at Kasauli. The egg measures 0·52 mm. long by 0·14 mm. greatest breadth. The coloration of the egg is described as soft grey and the demarcated portion at the micropilar end as shining black.

A. **multicolor** Cambouliu, 1902.*

The following is a translation of the description given by Foley (1912), for the eggs of *P. chaudoyei* (*A. multicolor*) :—

'Eggs 0·55 mm. long, disposed in rows : colour dull leaden grey, blackish olivaceous by transmitted light under the microscope. The rectilinear arrangement of the rows of eggs is brought about by the irregularly alternating disposition of the small and large extremities. The upper surface of the egg rather large, granular ; lower surface not ornamented. *No lateral floats.* Along the upper border of the

* Provisionally included in this group.

egg is a well developed striated fringe. which, at first applied to the egg, spreads itself out progressively to form at the two extremities flat frills which are the only organs of support. In the middle part of the lateral border this fringe is interrupted and leaves a wide space at the level of which the silvery membrane which covers the lower surface of the egg merges insensibly into the upper surface which is granular and blackish and unprovided with such membrane.'

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INDEX TO DESCRIPTIONS OF EGGS OF INDIAN SPECIES.

EXPLANATION OF PLATE I.

Fig. 1. Egg of *A. lindesaii* (type, Kasauli), dorsal and lateral view.
„ 2. Egg of *A. hyrcanus* var. *nigerrimus*, dorsal and lateral view.
„ 3. Ditto, three-quarter view.
„ 4. Egg of *A. tessellatus* (Andhra Valley, West Coast), dorsal and lateral view.
„ 5. Ditto, three-quarter view.
„ 6. Egg of *A. pulcherrimus*, dorsal and lateral view.

All figures to same scale as shown.

PLATE I.

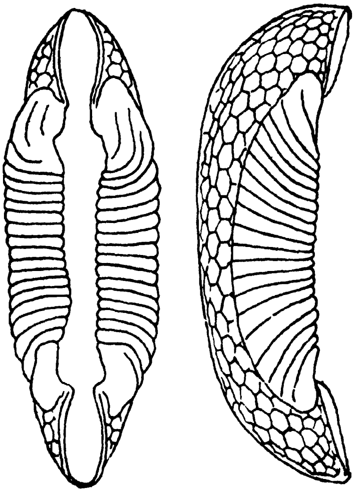


FIG. 1.

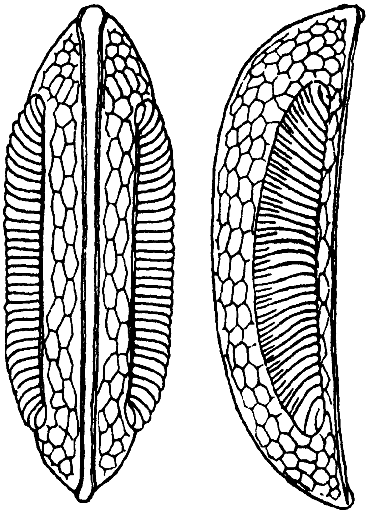


FIG. 2.

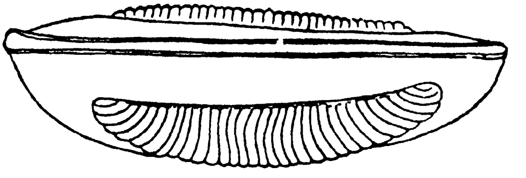
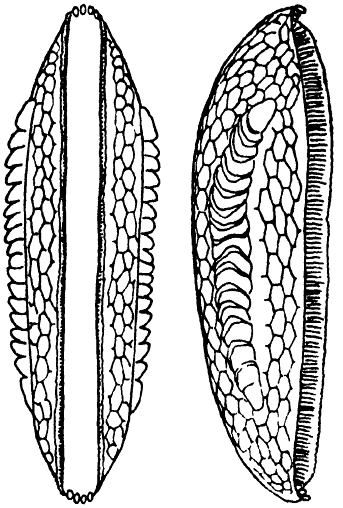


FIG. 3.



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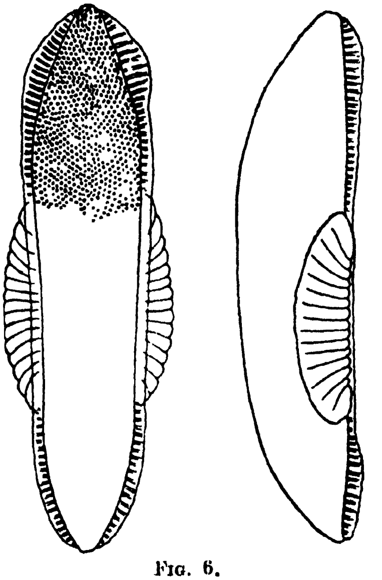

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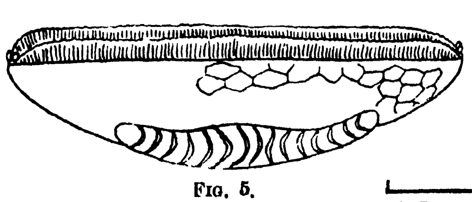


FIG. 5.

0.1 mm.

PLATE II.

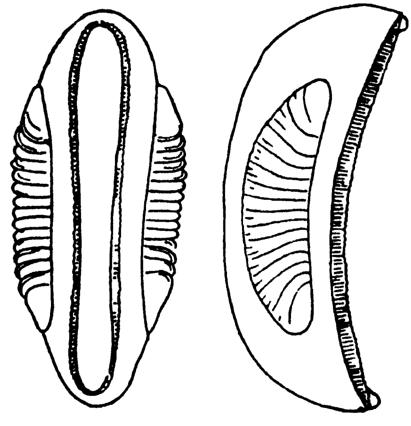


FIG. 7.

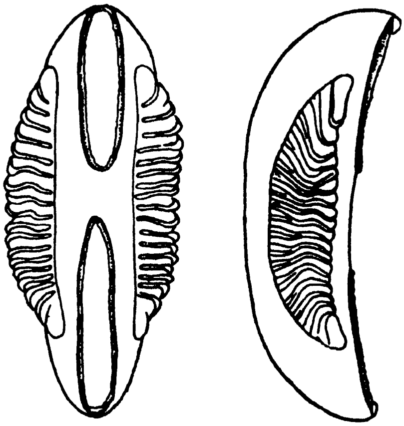


FIG. 8.

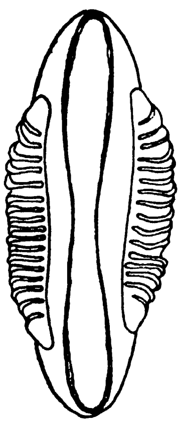


FIG. 9.

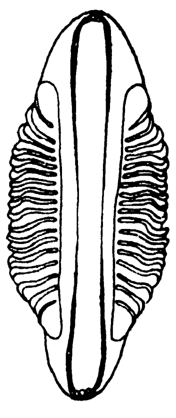


FIG. 10.

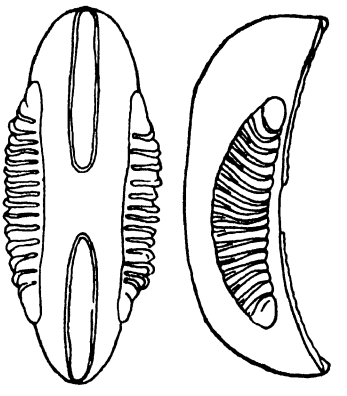


FIG. 11.

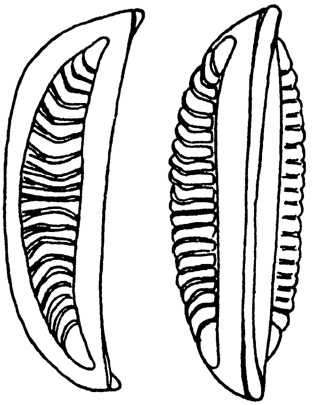


FIG. 12.

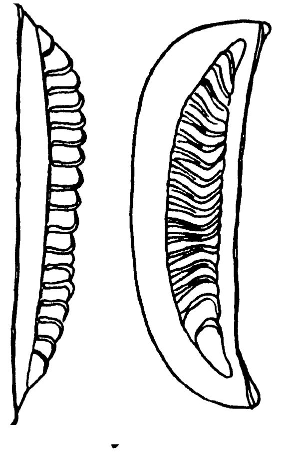


FIG. 13

0.1 mm.

Explanation of Plate II.

Fig. 7. Egg of *A. culicifacies*, dorsal and lateral view.

„ 8. Egg of *A. listonii* (Chakdara, N. W. F. Province), dorsal and lateral view.

„ 9. Ditto, showing form with single dorsal surface.

„ 10. Egg of *A. listonii* (Karnal) showing rather narrow straight deck (usual form as Fig. 8 or 9).

„ 11. Egg of *A. minimus* (?) (Bengal), dorsal and lateral view.

„ 12. Egg of *A. aconitus* (Budge Budge, Bengal), dorsal and lateral view.

„ 13. Egg of *A. aconitus* (Jeypore Hill Tracts), the figure on left drawn in floating condition.

All figures to same scale as shown.

EXPLANATION OF PLATE III.

Fig. 14. Egg of *A. subpictus*, dorsal, lateral and three-quarter view.

,, 15. Ditto, three-quarter view.

,, 16. Egg of *A. vagus*, dorsal and lateral view.

,, 17. Egg of *A. ludlowi* var. *sundaicus* (Budge Budge, Bengal), dorsal and lateral view.

,, 18. Egg of *A. moghulensis* (Andhra Valley, West Coast), dorsal and lateral view.

,, 19. Egg of *A. jeyporiensis* (Jeypore Hill Tracts), dorsal and lateral view.

PLATE III.

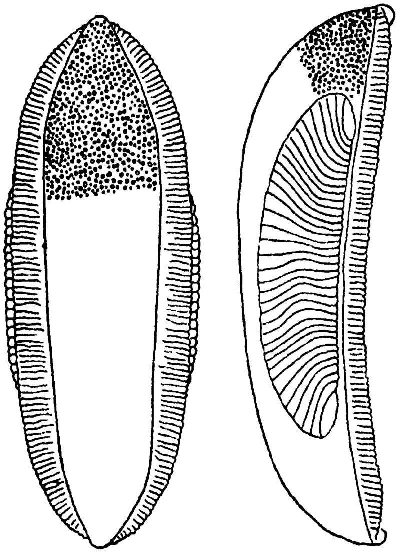


Fig. 14.

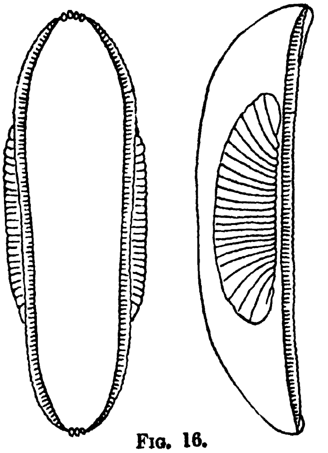


Fig. 16.

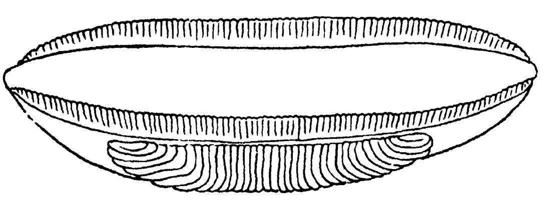


Fig. 15.

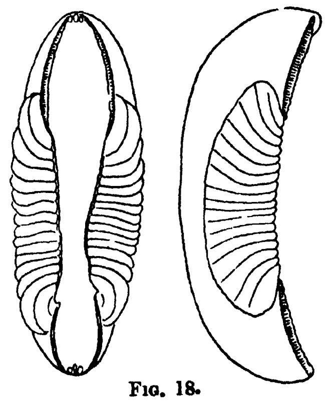


Fig. 18.

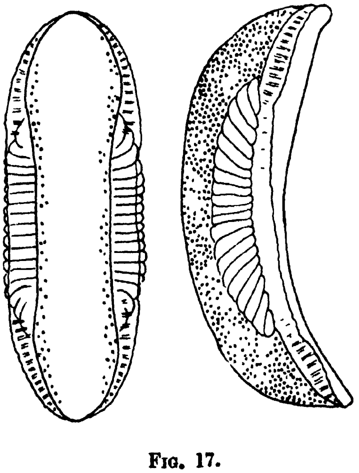


Fig. 17.

0.1 mm.

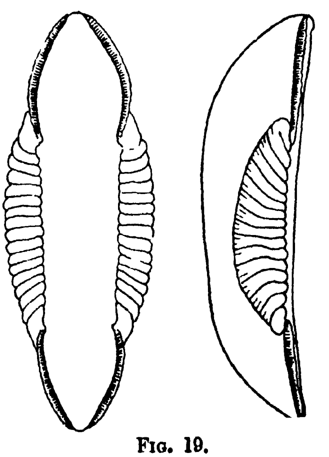


Fig. 19.

Plate IV.

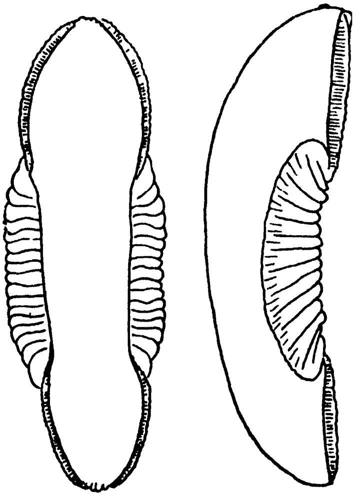


Fig. 20.

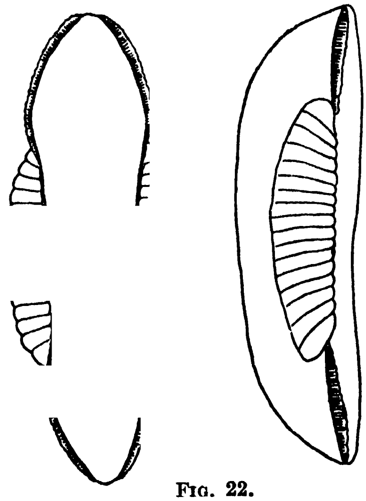


Fig. 22.

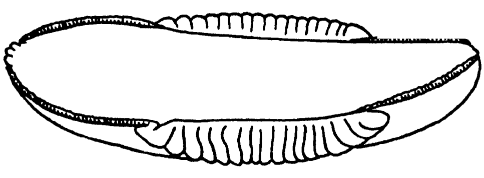
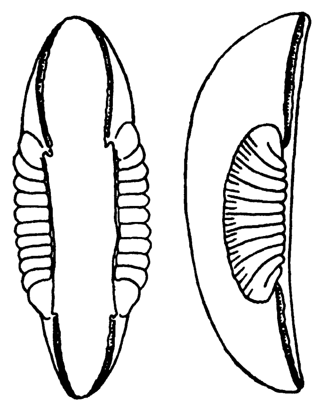


Fig. 21.



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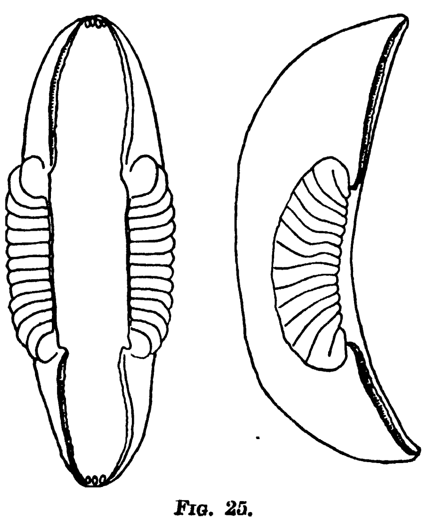

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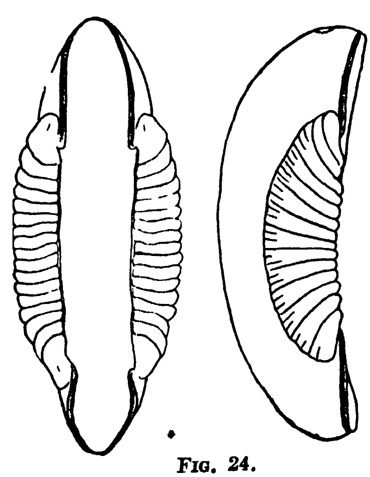

Fig. 24.

0.1 mm.

Explanation of Plate IV.

Fig. 20. Egg of *A. fuliginosus*, dorsal and lateral view.
,, 21. Ditto, three-quarter view.
,, 22. Egg of *A. pallidus*, dorsal and lateral view.
,, 23. Egg of *A. ramsayi* (Bengal), dorsal and lateral view.
,, 24. Egg of *A. jamesii* (Andhra Valley, West Coast), dorsal and lateral view.
,, 25. Egg of *A. stephensi*, dorsal and lateral view.
All figures to same scale as shown.

EXPLANATION OF PLATE V.

Fig. 26. Egg of *A. maculipalpis* var. *indiensis*, dorsal and lateral view.
,, 27. Egg of *A. maculatus* (Chakdara), dorsal view.
,, 28. Egg of *A. maculatus* var. *willmori*, dorsal view showing two of the variations seen in the dorsal surface.
,, 29. Ditto, lateral view.
,, 30. Egg of *A. turkhudi* (Punjab), dorsal and lateral view.
,, 31. Egg of *A. dthali* (after hatching of larva).
,, 32. Egg of *A. barbirostris* (Mysore), dorsal view.
,, 33. Ditto, lateral view.

All figures to same scale as shown, except Figs. 30 and 31 which are on different scales.

Plate V.

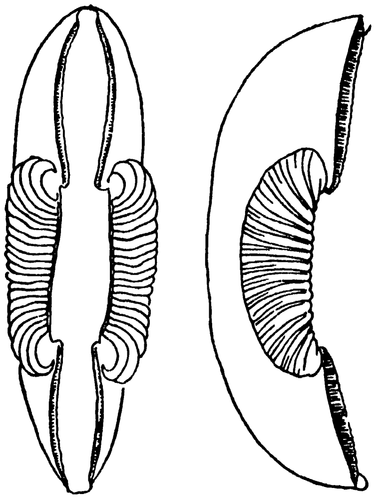

Fig. 26.

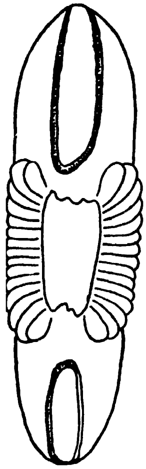

Fig. 27.

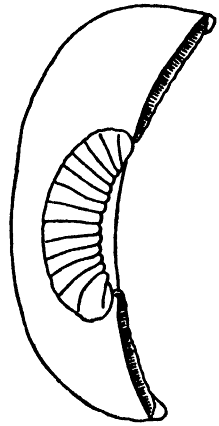

Fig. 29.

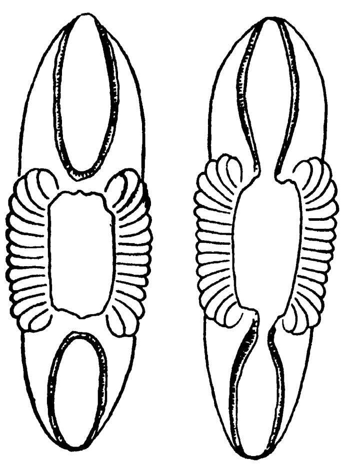

Fig. 28.

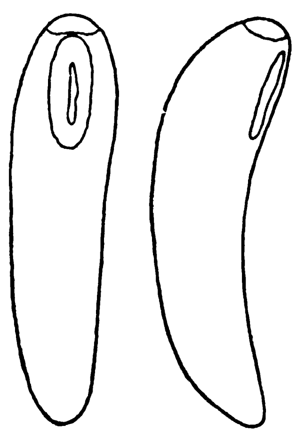

Fig. 30.

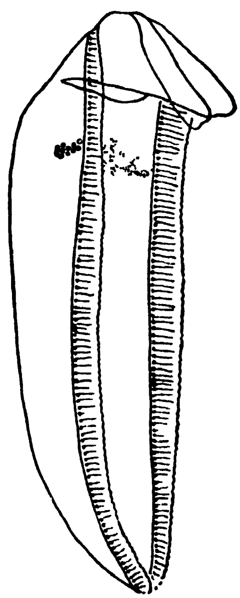

Fig. 31.

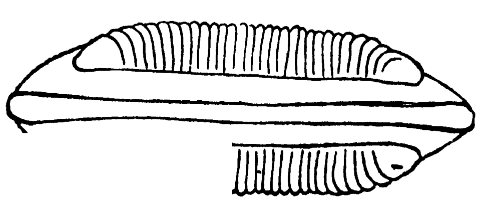

Fig. 32.

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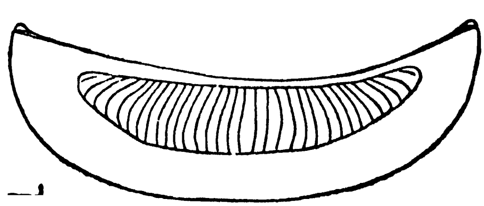

Fig. 33.

Records of the Malaria Survey of India, Vol. II, No. 2, June, 1931.

MOSQUITO SURVEY AT BIRNAGAR.

BY

K. BOSE,

Honorary Secretary, Birnagar Palli Mandali.

ERRATA

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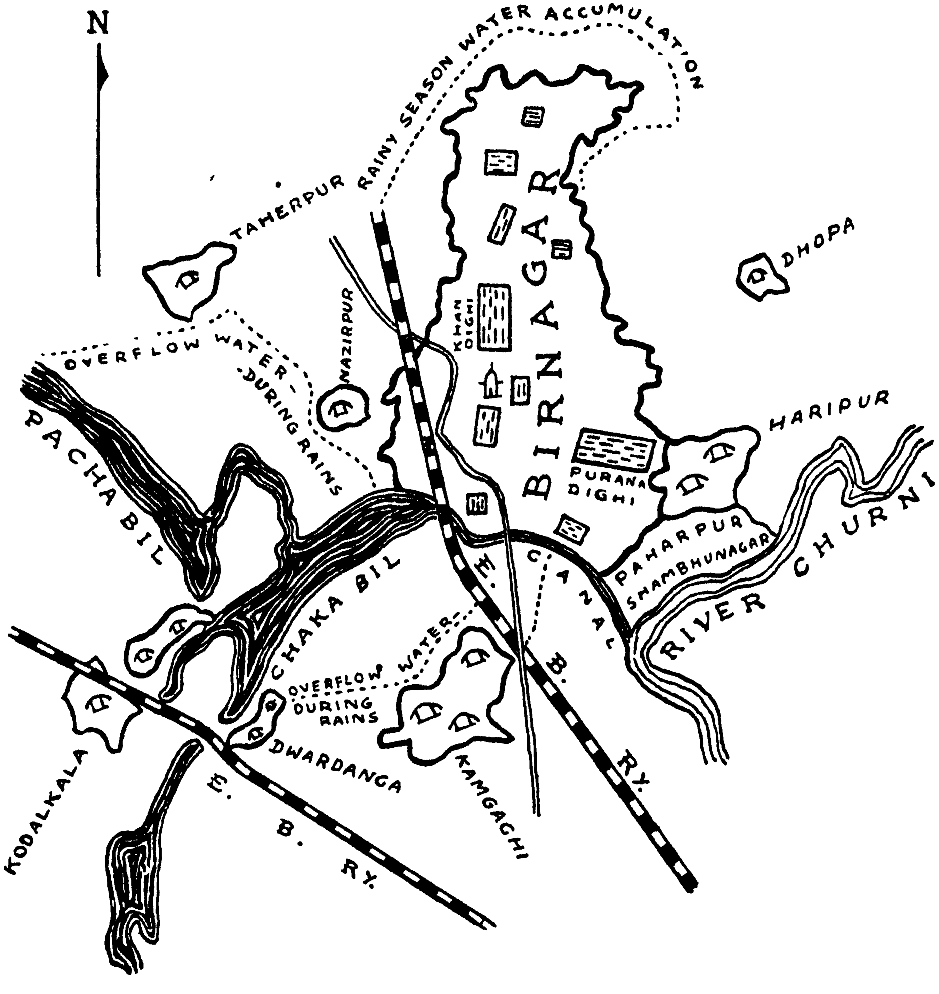
Malaria Research Laboratory. The observations and conclusions in this chapter are mine, and are based on the data collected at Birnagar under my direction and on those supplied by the two expert entomologists of the Government of Bengal, without whose warm and enthusiastic support nothing would have been possible. In this report I have thought it advisable not to include for consideration some small entomological work done by other workers at Birnagar prior to 1927.

LARVAL IDENTIFICATION.*

The Mandali has been carrying on anti-mosquito work since 1924 and mass quininization since 1926, subject to certain limitations. The survey work was carried out in the midst of these important duties. The staff

* The names *rossi*, *sinensis* and *pseudo-jamesi* which were used in the MSS. of this paper have been changed, with the author's permission, to *subpictus*, *hyrcanus* var. *nigerrimus* and *ramsayi* to conform with the nomenclature used by the Malaria Survey of India.—ED.

employed by the Mandali for the mosquito survey varied from year to year according to the funds available each year, which accounts for the paucity of collections during 1927 and 1928. A register for recording the breeding frequency of Anopheline mosquitoes from month to month was opened in 1927, but although collections were recorded as far as possible, all of them could



Birnagar and its environments.
Scale one inch = 1 mile.

not be despatched to Calcutta for identification. The despatch of collections became more regular from December 1928, and larval collections were sent periodically. It was noticed that some larvæ died in transit to Calcutta, and although this deficiency was made up by a periodical supply, particularly during 1929, it would be proper for scientific calculation to hold that there is a chance of error in the percentages of the species tabulated, as the ability

of the different species to survive the conditions of transit in bottles varies considerably. We examined the breeding grounds as often as was practicable, so that we might get as detailed information as possible about them. Our records are more complete with reference to certain breeding grounds than others. Having regard to this we may not be strictly justified in making a comparison of the figures for the three years tabulated below, as conditions were not identical.

STATEMENT I.

Larval collections made at Birnagar and identified by Mr. Iyengar during the three years, 1927-28 to 1929-30, the year running from April to March.

Species.	1927-28.	Percentage.	1928-29.	Percentage	1929-30.	Percentage.
A. fuliginosus	*528	42·7	†629	23	1,295	27
A. pallidus	..	..	40	1·4	137	3
A. philippinensis	..	..	114	4	330	7
A. rossi-vagus ‡	320	25 9	1,177	43	2,196	45·3
A. hyrcanus var. *nigerrimus* ..	250	20	334	12	451	9
A. minimus var. *varuna* ..	5	0·4	29	1	40	0·82
A. ramsayi	14	1	9	0·3	91	1·88
A. barbirostris	117	9·4	337	12	251	5
A. tessellatus	1	0·08	22	0·76	33	0·68
A. culicifacies	0	0	1	0·03	0	0
TOTAL COLLECTIONS ..	1,235	..	2,742	..	4,824	..

* Includes *pallidus* and *philippinensis* which were grouped under *fuliginosus* during this year.
† *Pallidus* and *philippinensis* were separated from *fuliginosus* in September 1928.
‡ Includes both *A. subpictus* and *A. vagus*.

It will be observed from this statement that 10 Anopheline species* were found breeding in all permanent and temporary collections of water at Birnagar. A brief description of the breeding grounds will be helpful in forming an idea of the work done by the Mandali. Most of the tanks, some of which are very large, have water in them throughout the year. The Khan Dighi, the largest tank, covers 7 acres of land and the Mustaphi Dighi, 4 acres. There are several other tanks whose area varies from 1 to 2 acres. Of temporary collections of water, the most important is the Purana Dighi, an old silted-up tank measuring about 12 acres, where water collects over a considerable area during the rains. There are several wide depressions and numerous hollows which

* *A. subpictus* (*rossi*) and *A. vagus* are shown as one species.

are full during the rains. The total number of breeding grounds of varying surface areas and depths is about 200.

The Baromeshey Canal, which forms the southern boundary, once served the purpose of natural drainage of Birnagar. At present flood water from the Churni, 2 miles east of Birnagar, passes through this channel to Chaka Bil, a lake on the south-west of Birnagar. This Bil is situated outside the Municipal area.

We have commenced a survey of the environments of the Birnagar Municipality up to a distance of 2 miles, which includes Chaka and Pacha Bils and the low-lying rice fields on the west and the river Churni on the east. Whatever results we have so far obtained from our partial survey of these places will be mentioned in elucidating our findings at Birnagar.

Comparison of larval findings.

It will not be out of place to compare the larval findings of Mr. Iyengar from the collections made by the Mandali at Birnagar with those of Dr. P. Sur and Dr. C. Strickland from the collections made by them in the neighbouring area covering the villages round about Krishnagar and the town of Krishnagar itself respectively.

Statement II.

Larval collections made in the villages around Krishnagar by Dr. Sur during 1927 and 1928.

Larval collections made in the town of Krishnagar and rural areas adjacent to it by Dr. Strickland in September 1926 and in January 1927.

Species.	1927.	1928.	Species	September 1926 and January 1927.
			A. fuliginosus ..	133
fuliginosus group, consisting of *A. fuliginosus*, *A. pallidus* and *A. philippinensis*	2,370	2,205	*A. pallidus*	1
			A. subpictus	35
'*rossi-vagus*' group* ..	9,744	20,732	*A. vagus*	138
A. hyrcanus var. *nigerrimus*	1,114	1,194	*A. rossi-vagus** ..	11
A. minimus var. *varuna* ..	24	22	*A. hyrcanus* var. *nigerrimus*	141
A. ramsayi	210	70	*A. aconitus*	2
A. barbirostris	772	1,952	*A. jamesii*	3
A. tessellatus	30	91	*A. jamesii x*†	3
A. culicifacies	30	17	*A. barbirostris* ..	31
			A. stephensi	1

* Including both *A. subpictus* and *A. vagus*. † This is *A. ramsayi* (*pseudo-jamesi*).

In his report for 1926-28 Dr. Sur says that so far as his findings of the villages around Krishnagar are concerned no difference was made in the identification of larvæ between *A. subpictus* and *A. vagus.* Further, owing to the difficulty in differentiating the larvæ of *A. fuliginosus, A. pallidus* and *A. philippinensis,* all of them were grouped under *fuliginosus.* Notwithstanding this explanation discrepancies in regard to certain other species are noticed. I shall endeavour to solve them as far as possible, so that the problem at Birnagar may be properly understood.

Dr. Sur's list does not contain *stephensi, jamesii* and *aconitus,* while Dr. Strickland does not mention *culicifacies, tessellatus* and *minimus* var. *varuna.* Although Dr. Sur failed to find *stephensi* in rural areas he found it breeding in wells in the town of Krishnagar. He found *culicifacies* larvæ in large numbers in the Jelanghi during the months January to March. Presumably Dr. Strickland did not make any collection from this river. It is quite possible for any one making a short survey to overlook a few species, such as *tessellatus.* Did Dr. Strickland fail to find *minimus* var. *varuna* larvæ for the same reason? What is the reason of Dr. Sur's missing *aconitus* in his systematic survey ? It seems to me that where the two experts allude to *minimus* var. *varuna* and *aconitus* they refer to one and the same species. The point is important, and I shall revert to it later. The discrepancy about *jamesii* is not understood, as the general impression of the Public Health Department, Bengal, is that this species is absent in deltaic Bengal

SEASONAL VARIATIONS OF BREEDING.

In order to determine roughly the seasonal variations of breeding of Anopheline species at Birnagar during the last three years, I have tabulated the figures in Statement III under three seasons, viz., summer (April to June), rainy, including the entire epidemic period (July to November) and winter (December to March of the following year).

I have already stated that our larval collections have been more regular since December 1928. In the winter of 1928-29 and the summer of 1929 we carried out a systematic examination of all permanent reservoirs of water and those pools which had not dried up at the time. In the rainy season we re-surveyed some of them, and in addition managed to examine a large number of temporary pools which formed at that time. Owing to the sandy soil some of the shallow pools dry up after a spell of sunny weather. Most of these could not be examined, but by their very nature they cannot be classed as breeding places of a serious character. Those that were examined contained larvæ of *subpictus* and *fuliginosus* or *hyrcanus.*

I have placed before the reader the details of the larval findings and I shall now give figures in regard to adults and then proceed to a discussion of the problem.

STATEMENT III.

Seasonal variations of breeding of Anopheline species at Birnagar during the three years 1927-28 to 1929-30.

Species.	April 1927 to March 1928.			April 1928 to March 1929.			April 1929 to March 1930.		
	April to June.	July to November.	December to March.	April to June.	July to November.	December to March.	April to June.	July to November.	December to March.
A. fuliginosus ..	12* (6 per cent).	*375 (49·5 per cent).	*141 (50·5 per cent).	*29 (14 per cent).	*85 (14·8 per cent).	515 (26 per cent).	316 (16 per cent).	510 (24 per cent).	469 (61 per cent).
A. pallidus ..	..	..	..	..	..	40 (2 per cent).	75 (3 8 per cent).	40 (1·9 per cent).	22 (2·8 per cent).
A. philippinensis	..	..	..	..	6 (1 per cent).	108 (5·5 per cent).	198 (10 per cent)	102 (4·8 per cent).	30 (3·9 per cent).
A. rossi-vagus ..	187 (94 per cent).	114 (15 per cent).	19 (6·8 per cent).	170 (82·9 per cent).	250 (43·5 per cent).	757 (38 5 per cent).	1,232 (63 5 per cent).	898 (42 per cent).	66 (8·5 per cent).
A. hyrcanus var. *nigerrimus.*	0	156 (20 6 per cent).	94 (33·7 per cent)	6 (2·9 per cent).	106 (18·4 per cent).	272 (13·8 per cent).	15 (0·7 per cent).	326 (15 per cent).	110 (14 per cent).
A. minimus var. *varuna.*	0	5 (0·6 per cent).	0	0	3 (0·5 per cent)	26 (1·3 per cent).	3 (0·15 per cent)	30 (1·4 per cent).	7 (0·9 per cent).
A. ramsayi ..	0	6 (0·79 per cent).	8 (2·8 per cent)	0	2 (0·3 per cent)	7 (0·35 per cent).	68 (3·5 per cent).	3 (0·14 per cent).	20 (2·6 per cent).
A. barbirostris ..	0	100 (13 per cent).	17 (6 per cent).	0	107 (18·6 per cent).	230 (11·7 per cent).	0	208 (9·8 per cent).	43 (5·6 per cent).
A. tessellatus ..	0	1 (0·13 per cent).	0	0	15 (2·6 per cent).	7 (0·35 per cent).	31 (1·6 per cent).	2 (0·09 per cent).	0
A. culicifacies ..	0	0	0	0	0	1 (0·05 per cent).	0	0	0
TOTAL LARVÆ ..	199	757	279	205	574	1,963	1,938	2,119	767

* Includes *A. pallidus* and *A. philippinensis*, which were separated from *A. fuliginosus* in September 1928.

Mosquito collection.

Collection of mosquitoes was made at Birnagar by an employee of the Krishnagar Research Laboratory helped by two of the employees of the Mandali during their spare hours. Traps were used to a small extent. In 1929 collections from each Municipal Ward were kept separate and identified accordingly, except in the case of a few collections the exact location of which was not recorded. Collections were made mostly in the morning, except from August to November 1929, when special arrangement was made to collect mosquitoes between the hours 8 P.M. and midnight in addition to day collections. These were identified separately for each Ward. More houses were visited in 1929 than in 1928. Altogether 60 houses at Birnagar, both 'pucca' and thatched, were examined during 1929 on three or four days in the week, as arranged by Dr. Sur.

It is ordinarily believed that, unless a very large number of Anopheline mosquitoes are caught from all localities in the area under investigation and dissected, it may not be possible to come to any definite conclusion regarding the respective prevalence of the different species in that area and their infectivity rate. A society like the Mandali has to work under considerable financial limitations, and it was obliged to restrict its scope according to the funds at its disposal.

The number of mosquitoes collected at Birnagar and dissected are stated below:—

Year.	Collected.	Dissected.
July-December 1928	2,647	1,843
April-December 1929	5,815	3,159

Even though these collections appear to be small, very important findings have been brought to light.

Identification of mosquitoes and conditions governing their prevalence.

The following adult Anopheline species were identified by Dr. Sur from the collections mentioned above:—

Collection of adults in dwelling houses, if it embraces all localities and different types of houses, ought to give us a rough indication of the species visiting them. Certain species have a preference for cow's blood or the juice of vegetables, and may not frequent dwelling houses to any large extent. There may be an influx of certain species of mosquitoes from outside our borders. The marked difference in percentages between the larval and adult collections of some of the species as set forth in Statements I and IV may generally be attributed to these causes.

STATEMENT IV.

Adult Anophelines collected at Birnagar and identified by Dr. Sur during the years 1928 *and* 1929.

Species.	1928.		1929.	
A. fuliginosus	977	(37 per cent)	2,053	(35 per cent)
A. pallidus	295	(11 „)	631	(11 „)
A. philippinensis	591	(22 „)	266	(4·6 „)
*A. rossi-vagus**	497	(18·7 „)	1,328	(22·7 „)
A. hyrcanus var. *nigerrimus* ..	117	(4 „)	104	(1·8 „)
A. minimus var. *varuna* ..	31	(1 „)	50	(0·85 „)
A. ramsayi	135	(5 „)	1,381	(23·8 „)
A. barbirostris	4	(0·15 „)	2	(0·03 „)
TOTAL ..	2,647		5,815	

* Includes *A. subpictus* and *A. vagus.*

A comparative statement showing the percentages of mosquito larvæ and mosquitoes collected at Birnagar during the fever season, 1929, is given below:—

STATEMENT V.

Total collections from July to November 1929.	Larvæ. 2,119	Mosquitoes. 3,541
A. fuliginosus	24 per cent	38 per cent
A. pallidus	1·8 „	11 „
A. philippinensis	4·8 „	5 „
*A. rossi-vagus**	42 „	14·7 „
A. hyrcanus var. *nigerrimus* ..	15 „	2 „
A. minimus var. *varuna* ..	1·4 „	1 „
A. ramsayi	1·5 „	27 „
A. barbirostris	9·8 „	0·06 „
A. tessellatus	0·1 „	0 „

* Includes *A. subpictus* and *A. vagus.*

From the observations made at Birnagar during the years 1924 to 1928 we know that with the advent of the winter season mosquitoes become inactive,

i.e., they do not torment human beings, although they never cease to breed in tanks. There is a short break in inactivation during the spring season, owing to the late winter showers. With the approach of the hot weather mosquitoes again retire and remain inactive till the monsoon, when the usual break in inactivation takes place. The mosquitoes then commence to infest the houses. These peculiarities in the behaviour of mosquitoes explain why we cannot make as large a collection of them in the winter and hot seasons as during the rains. As the rainy season advances the mosquitoes multiply, and consequently become numerous in October and November. When the cold weather sets in Nature lulls them again to inactivity. The curve of fever incidence at Birnagar rises when there is a break in inactivation, and as soon as the mosquitoes retire with the approach of the cold season the fever curve falls rather abruptly. This has been explained in my annual reports issued previously. It would be fallacious to incriminate certain species as carriers merely because their prevalence corresponds to the rise in the curve of fever incidence. Except the *rossi-vagus* group, whose prevalence is governed by breeding partly in artificial reservoirs of water in dwelling houses and partly in tanks and pools, and *barbirostris* which rarely frequents the dwelling houses at Birnagar, all other species (tank and pool breeders) behave more or less alike in this respect as will be seen from the table below:—

STATEMENT VI.

Species	Maximum prevalence.	
	1928.	1929.
A. fuliginosus	October	October
A. pallidus	November	December
A. philippinensis	November	August
A. hyrcanus var. *nigerrimus* ..	October	September
A. ramsayi ..	October	October
A. minimus var. *varuna* ..	October	December

The 1928 list gives us a fairly correct idea of the maximum prevalence of the various species at Birnagar under conditions which, though not strictly normal, were not much vitiated by a general anti-mosquito campaign carried under considerable limitations. Following the recommendations made by Sir Malcolm Watson in February 1929, we modified our campaign by taking special measures against *philippinensis* breeding. The difference in the time of the maximum prevalence of *philippinensis* during 1928 and 1929 is a serious

one, and will be examined later. The discrepancies regarding *pallidus* and *minimus* var. *varuna,* whose maximum prevalence in 1929 was in December cannot be said to be material when compared with the figures for October and November of that year. It seems to me that the results of dissections of Anopheline mosquitoes is a more reliable guide in apportioning the blame. The mosquito prevalence curve alone is insufficient to condemn a particular species.

RESULTS OF DISSECTION AND HABITS OF SPECIES.

Let us now proceed to an examination of the results of dissection of the Anopheline mosquitoes collected at Birnagar, and to a determination of the carrier species at Birnagar.

A. culicifacies.—This species is a well-known malaria carrier, particularly in Northern India and the Madras Presidency. During our three years' survey we found only one *culicifacies* larva and no adults. My impression is that it is not a local species at Birnagar, and that the single larva that has been traced is evidence of the presence there of a few adults of that species which are carried to Birnagar by train from Krishnagar, where it breeds in the river Jelanghi, which is 14 miles north of Birnagar. No *culicifacies* larvæ were found in the Churni during our survey of that river from December 1929 to June 1930, when flood stopped breeding of other species.

A. subpictus, A. vagus, A. hyrcanus and *A. barbirostris* are generally acknowledged in India as non-carriers or carriers of minor importance, and Dr. Sur's dissection results confirmed this impression, though it must be said that our collection of the last two named species has been very small. But we found them in good numbers in the larval stage, *vide* Statement I. Possibly they have a dislike for human blood and that is why we found adults in insignificant numbers in dwelling houses, *vide* Statement IV. From the figures compiled by Dr. Sur, it appears that *hyrcanus* has a preference for cattle-sheds, and that *barbirostris* seems to avoid both dwelling houses and cattle-sheds.

Species.	Cattle-sheds. Per cent.	Dwelling houses. Per cent.
A. hyrcanus var. *nigerrimus*	2·7	1·8
A. barbirostris	0·17	0·05

It may be mentioned, however, that we made no attempt to collect Anopheline mosquitoes from the jungle and undergrowth. Possibly an investigation in this direction will throw new light on the habits of certain species.

A. ramsayi (*pseudo-jamesi*) has been found to contain malaria parasites in Cachar, Assam, both by Dr. Strickland and by Dr. Ramsay.* The former

* The figures given by Ramsay include those given by Strickland, so that the one infection recorded by each observer refers to the same specimen —ED.

Statement VII.

Results of dissection of Anopheline mosquitoes collected at Birnagar during the years 1928 (*July to December*), 1929 (*April to December*), *and the early part of* 1930 (*January to April*).

(Number found infected is shown in brackets; *s* stands for sporozoites, *z* for zygotes and *sz* for both sporozoites and zygotes.)

1928.

Months.	*fuliginosus.*	*pallidus.*	*philippinensis.*	*rossi-vagus.*	*hyrcanus.*	*minimus* var. *varuna.*	*ramsayi.*	*barbirostris.*
July	2	0	0	18	0	0	1	0
August	10	6	25 (1*z*)	59	0	0	0	0
September	102	43	80 (2*s*, 1*sz*)	86	3	2	4	0
October	237	70	110 (2*s*, 2*z*)	3	32	2	69	1
November	310	89	181 (1*sz*, 1*s*, 3*z*)	0	33	9	15	0
December	126 (1*s*)	26	62	0	6	8	10	3
Total number dissected ..	787	234	458	163	74	21	99	4
Total number infected ..	1	0	13	0	0	0	0	0
Percentage of infection ..	0·12	..	2·8	..	..	..	..	..

1929.

Months.	*fuliginosus.*	*pallidus.*	*philippinensis.*	*subpictus.*	*vagus.*	*hyrcanus.*	*minimus* var. *varuna.*	*ramsayi.*	*barbirostris.*
April	20	2	14	4	0	0	1	38	0
May	137	16	39	253	1	7	1	14	0
June	102	13	13 (1z)	87	0	0	1	50	0
July	59	10	12	66	3	1	1	46	0
August	90	23 (1z)	44	40	78	10	4	96	0
September ..	328	95	26	0	16	17	7	120	0
October ..	126	17	27	0	0	15	5	81	0
November ..	197	105	20 (1z)	0	0	7	6	148	0
December ..	155	122	1	0	0	2	4	116	0
Total number dissected.	1,214	403	196	450	98	59	30	709	0
Total number infected.	0	1	2	0	0	0	0	0	0
Percentage of infection.	..	0·25	2	..	..	..	..	..	..

1930.

Months.	*fuliginosus.*	*pallidus.*	*philippinensis.*	*subpictus.*	*vagus.*	*hyrcanus.*	*minimus* var. *varuna.*	*ramsayi.*	*barbirostris.*
January ..	111	48	0	0	0	3	15	88	2
February ..	53	16	0	0	0	4	6	117	0
March ..	81	7	5	4	1	13	0	193	0
April ..	58	4	2	1	0	7	0	33	0
Total number dissected.	303	75	7	5	1	27	21	431	2
Total number infected.	0	0	0	0	0	0	0	0	0

found one specimen with glands infected out of 256 specimens collected in 1927. Dr. Strickland writes about this species as follows in the *Journal of Medical Research* for July 1929:

'In a report on a mosquito survey of the Bengal districts (Strickland and Chowdhuri, 1927) it was stated "in view of the difficulty experienced by epidemiologists in the past in allocating the malaria of the Province to any specific cause, this find of *pseudo-jamesi* may prove of great importance." In this Cachar survey its number and infectivity indicate that it may be about 340 times less infective than *funestus*.'*

From our larval investigation we notice that the percentage of collection of *ramsayi* rose from 0 3 per cent in 1928-29 to 1·88 per cent in 1929-30, i.e., 6¼ times. This may not mean much, as our larval collections during the former year were not as comprehensive and systematic as in the latter. But the percentage of collection of adults of this species also rose from 5 per cent in 1928 to 23 per cent in 1929, i.e., 4¾ times. As soon as we came to realize the position in regard to the latter early in autumn, we started an investigation and found *ramsayi* breeding in certain pools on the western side of Birnagar which were left out from our scope of oiling, partly owing to the difficulty of access to them and partly owing to shortness of funds. We also found *ramsayi* larvæ in Chaka Bil on the south-west of Birnagar and even in Pacha Bil, 2 miles west of Birnagar (*vide* Map of Birnagar). We however could not extend our examination to the low-lying rice fields between Birnagar, Chaka Bil and Pacha Bil, which become submerged during the rains but dry up in the winter. It is probable that owing to some unknown biological factor this species found a favourable opportunity to multiply not only at Birnagar but in the Bils, and possibly in the rice fields mentioned above. Very likely there was some influx of this species from these regions into Birnagar during 1929. In one respect this incursion was welcome for we got an opportunity to test its infectivity. Dr. Sur dissected 709 specimens in 1929 compared with 99 specimens in 1928. Not a single specimen was found infected by him. We may therefore conclude that this species cannot do any serious mischief at Birnagar. It may be mentioned that the Director, Malaria Survey of India, does not consider it likely that this species plays an important part as a malaria carrier in Bengal.

A. minimus var. *varuna*.—This name has been given to a varietal form of *A. minimus* which was discovered by Mr. Iyengar, who found it in large numbers in the environments of Calcutta. Dr. Sur found it in small numbers in areas around Krishnagar and the identification reports of Dr. Sur and Mr. Iyengar also indicate that it has a small prevalence at Birnagar. Mr. R. Senior-White, Malariologist, B. N. Railway, and Dr. G. C. Ramsay, whose opinions I sought, thought this species to be the principal malaria carrier at Birnagar, and they advised me to make a thorough search for it. In 1929 we

* = *A. minimus*.—Ed.

tried our best to locate all its breeding grounds and the result of our labours in regard to larval and adult collections is noted below:—

1929.

	Total collections (all species).	*A. minimus* var. *varuna* only.	Percentage.
Larvæ	4,824	40	0·8
Adults	5,815	50	0·85

The number of breeding grounds of this species was found to be limited, and larvæ in insignificant quantity only could be found in them, except in one pool covered with thick vegetation in a low-lying rice field below the Municipal Office, where 20 larvæ were found in March 1929. This pool dried up in summer, and remained submerged under a large expanse of water during the rains and autumn (fever season), when no *minimus* var. *varuna* larva could be traced. When the large expanse of water receded in the winter, exposing the pool, this species reappeared Such behaviour of this species in low-lying lands in other parts of Bengal was previously noticed by Mr. Iyengar. Dr. Sur did not find any infected specimen among our small collection of adults during 1928 and 1929.

In view of the discrepancy between our findings and the strong opinions expressed by two of the specialists named above, I thought it essential in the interest of the malarial problem at Birnagar to have the matter further investigated. Eight of the adult specimens of the species which were identified at Krishnagar as *minimus* var. *varuna* were described as *aconitus* by the Calcutta School of Tropical Medicine. The Malaria Survey of India after examining five of these mosquitoes reported as follows:—

'*Anopheles aconitus* .. .. .. 5 females.

These appear to be fairly typical specimens and possess the following characters.—

> Palpi with two broad distal bands of about equal width, proboscis pale in apical half, 6th vein with 3 dark areas, fringe spot at tip of 6th vein; 3rd vein extensively pale and without a dark area at the base.

(Sd.) P. J. BARRAUD,
Entomologist, Malaria Survey of India'

5th July, 1930.

From the above it appears that some *aconitus* specimens were mixed up with *minimus* var. *varuna* in our collection. It is understood that the larval stages of these two forms are also not easily distinguishable. The two species are now being identified separately.

Dr. Strickland considers *aconitus* to be a carrier species, and he ascribes his failure to find any infection in it in Cachar, Assam, to the insufficiency of collection (Strickland, 1929, p. 177). On the other hand Dr. Ramsay says that it is one of the prevalent species in Cachar, that it seems to prefer feeding on cow's blood, and that he did not find a single specimen to be infected. The Director, Malaria Survey of India, supplies the following information about *aconitus:*

'This species has only once been found infected in nature in India. Dr. Feegrade in Burma found one gut infection out of 58 specimens dissected. Previously Lalor in Burma dissected 165 specimens which were all negative. Dr. Ramsay in Assam has dissected 1,661 specimens and these were all negative.'

If our adult and larval collections of *minimus* var. *varuna* as noted above are a reliable guide to its prevalence at Birnagar, and as we have now to separate *aconitus* from it, our grounds for suspecting any of these species to be malaria carriers of any importance at Birnagar become extremely frail.

It may be mentioned that Dr. Sur's results of dissection of mosquitoes of all the species named above collected from the rural areas around Krishnagar was also negative.

It now remains for me to deal with *A. fuliginosus*, *A. pallidus* and *A. philippinensis,* all of which were found to be infected in nature either at Birnagar or in the areas around Krishnagar, 12 miles north of Birnagar. It is thought therefore that the findings near Krishnagar will also be helpful to us in arriving at a conclusion in determining the principal malaria carrier at Birnagar. As *pallidus* and *philippinensis* were separated from *fuliginosus* at the Krishnagar Laboratory about the end of the year 1927, a useful comparison of the Birnagar figures with those of Krishnagar can only be made for the years 1928 and 1929.

A. fuliginosus.—The infectivity of this species at Birnagar and Krishnagar is shown below:—

STATEMENT VIII.

Year.	Locality.	Total number dissected.	Number found infected.	Month in which infected.
1928	Birnagar ..	'787	1*s*	December
,,	Krishnagar ..	1,703	1*s*	February
1929	Birnagar ..	1,214	0	..
,,	Krishnagar ..	1,033	0	..

s = sporozoites.

From an examination of the registers of mosquito and larval collections at Birnagar, it would appear that although this species is prevalent throughout

the year its maximum prevalence is in October, and its maximum breeding is in January and February. The numerous tanks at Birnagar, some of which are of large dimensions, provide favourite breeding grounds for this species during the winter. The adults, however, become inactive during this season, i.e., they do not generally torment human beings, though they never cease breeding. Dr. Sur, however, found it mainly an autumn breeder, possibly because there are no big permanent reservoirs of water in the villages around Krishnagar like those of Birnagar, and consequently little scope exists for extensive breeding. Notwithstanding the fact that the prevalence of adults was greatest when the fever season was at its highest it failed to carry infection at the time. On the other hand one specimen was found infected in the season when malaria was not much in evidence. This was the case at Krishnagar also. All this points to the fact that this species is not liable to become infected in nature easily, even under the most favourable conditions, and that the single infected specimen found at Birnagar in 1928 merely suggests that it has a sporadic infectivity there. The mischief it can do may therefore be disregarded.

A. pallidus seems to have also a sporadic infectivity, as will be seen from the figures given below, and may be disregarded as a malaria carrier of any importance.

STATEMENT IX.

Year.	Locality.	Total number dissected.	Number found infected.	Month in which infected.
1928	Birnagar ..	234	0	..
,,	Krishnagar .	438	0	..
1929	Birnagar ..	403	1z	August
,	Krishnagar ..	736	0	..

z=zygotes.

I have now one more species to deal with and that is *A philippinensis*, about the infectivity of which a serious difference of opinion exists between Dr. P. Sur on the one hand and Dr Strickland and Dr. Ramsay on the other. Before discussing this discrepancy let us examine the findings of Dr. Sur, who dissected the specimens sent to him from Birnagar and also collected by him

in the villages around Krishnagar. The following is the result of his dissection:—

STATEMENT X.

Dissection result of A. philippinensis, 1928 *and* 1929.

z = zygotes; *s* = sporozoites; *sz* = both sporozoites and zygotes.

Months.	Birnagar.	Krishnagar.	Birnagar.	Krishnagar.	Total dissected.	Number found infected.	Percentage of infection.
	1928.		1929.				
April ..	..	..	14	6	20	0	0
May ..	..	..	39	2	41	0	0
June ..	..	..	13 1*z*	2	15	1	6·6
July ..	..	..	12	2	14	0	0
August .	25 1*z*	..	44	25 1*s*	94	2	2
September ..	80 2*s* 1*sz*	8 1*s*	26	40 1*s* 1*z*	154	6	4
October ..	110 2*s* 2*z*	29 1*s*	27	59 2*s*	225	7	3
November ..	181 1*s* 3*z* 1*sz*	32 1*s*	20 1*s*	139 2*s*	372	9	2·4
December ..	62	12	1	31	106	0	0

The epidemic season at Birnagar and in Bengal generally extends from August to November, when malarial parasites were found in *A. philippinensis* in a systematic manner quite unlike *fuliginosus* and *pallidus*. I may mention that *A. minimus* carries infection in a similar way in Assam, as will be seen from Dr. Strickland's findings which are enumerated below (Strickland, 1929):—

STATEMENT XI.

Infectivity rate of A. minimus *in Cachar, Assam.*

	June.	July.	August.	September.	October.	November.
Number dissected ..	235	266	120	71	219	382
Number found infected	11	7	6	3	6	21
Percentage of infection	4·7	2·6	5	4	2·7	5·5

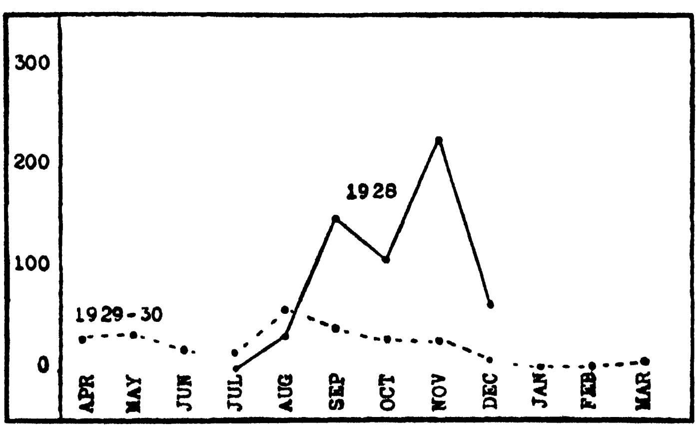
It will thus be observed that *minimus* in Assam and *philippinensis* in Bengal (or to be strictly accurate in the Nadia District), are systematic seasonal carriers of malaria, and if we compare their infectivity during the four months of our malarial season we find that *minimus* has greater potentiality for danger than *philippinensis*.

Species.	Numbers dissected.	Numbers found infected.	Percentage found infected.
philippinensis ..	845	24	2·8
minimus ..	792	36	4·5

Possibly the infectivity of *philippinensis* is much greater than the figures indicate, as the collection of adults of this species at Birnagar during September, October and November of 1929 was so small that no clear results were obtained. Excluding the *rossi-vagus* group, the total collection of all other species during these three months was 1,392 in 1928 and 1,347 in 1929, and although the collections of *fuliginosus* and *pallidus* were almost identical in number in both the years during the period mentioned, the number of *philippinensis* perceptibly decreased and that of *ramsayi* increased in 1929. I have already discussed the latter point elsewhere in this report. The reasons for the small collection of *philippinensis* during the fever season in 1929 will be explained below.

The graph below shows the variations in the prevalence of *philippinensis* at Birnagar during 1928 and 1929-30 and at Krishnagar during 1928 only.

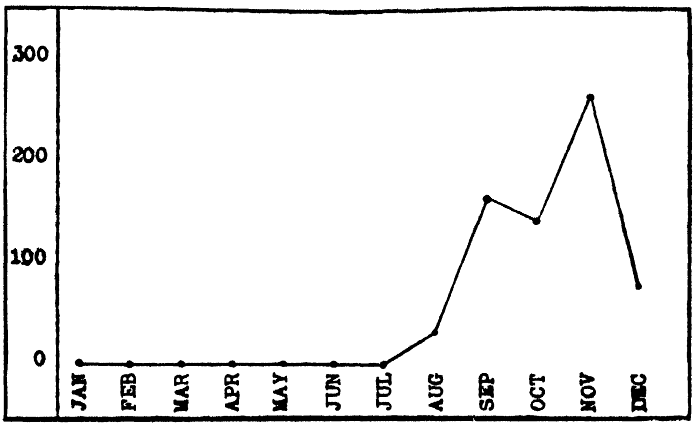
GRAPH 1.



Monthly variations in prevalence of *A. philippinensis* in dwelling houses at Birnagar.

The curves at Birnagar and Krishnagar during 1928 have several features in common, including the bi-modal character showing peaks in September and November. But as the Krishnagar figures for 1929 have not yet been published I am unable to compare the figures for those two places during 1929. So far as the Birnagar figures for 1929 are concerned it appears that after reaching

GRAPH 2.



Monthly variations in prevalence of *A. philippinensis* in dwelling houses at Krishnagar during 1928

the maximum in August the *philippinensis* curve began to fall steadily till it reached zero in February 1930. It is impossible to say if the anti-*philippinensis* campaign inaugurated in March 1929 had anything to do with this fall till we see what collections we get in subsequent years. Possibly the fall is purely artificial and may be ascribed to bad sampling. Against this it may be said that since there is no evidence of bad sampling in the cases of *fuliginosus* and *pallidus* it is unlikely that the *philippinensis* record is vitiated by this error. It will be further seen from the statement below that collections of *philippinensis* were particularly small in Wards I and II during the fever season, 1929:—

Ward I.	Ward II.	Ward III.	Ward IV.
4 per cent.	3 per cent.	23 per cent.	31·8 per cent.

But it may be stated that the entire water surface of a large marshy land in Ward I where *philippinensis* bred was treated with larvicides, whereas for want of sufficient number of boats and other causes certain water surfaces in Ward III could not be so treated.

It would be proper to assume that chances of bad sampling always exist in making larval and adult collections. The error due to this factor can be eliminated to some extent by grouping the figures. Where an organized attempt is made for such collections extending over a long period and a fairly large area the defects are greatly minimized, and the data give us approximately correct conclusions.

As the sampling of adults was made from all kinds of dwelling houses at Birnagar, each year's collection of the different species would indicate roughly their annual relative prevalence in dwelling houses. The average relative prevalence of the species in dwelling houses at Birnagar during the malarial season of 1928 and 1929 is indicated below:—

fuliginosus.	*pallidus.*	*philip-pinensis.*	*rossi-vagus.*	*hyrcanus.*	*minimus* var. *varuna.*	*ramsayi.*	*barbirostris.*
3,030	≡ 926	≡ 857	≡ 1,825	≡ 221	≡ 81	≡ 1,516	≡ 6
*Or, 505	≡ 154	≡ 143	≡ 304	≡ 37	≡ 13	≡ 253	≡ 1

* Taking *barbirostris* to be 1.

It might be justly argued that if a larger number of mosquitoes of other species were collected and dissected a rate of infection similar to that found in *philippinensis* would be noticed in some of them as well But if we were to compare their infectivity with that of *philippinensis* it would be necessary to determine this with reference to their average prevalence. From the data available at present we may classify the carrier species of Birnagar as follows:—

(1) Systematic seasonal carrier,
- (*a*) of first importance, viz., *A. philippinensis*,
- (*b*) of secondary importance (none yet found)

(2) Sporadic carriers of little importance, viz., *A. fuliginosus* and *A. pallidus*.

The discrepancies and their solution.

Having stated our findings I shall allude to the discrepancies. These concern the habits and infectivity of *philippinensis* in the two neighbouring provinces, Bengal and Assam. From the investigations made by Dr. Sur in the villages adjacent to Krishnagar it would appear that this species prefers to

frequent dwelling houses much more than cattle-sheds. This is clear from the table below:—

STATEMENT XII.

Comparative statement of the prevalence of species in dwelling houses and cattle-sheds compiled by Dr. Sur (1928).

	subpictus.	*vagus.*	*fuliginosus.*	*pallidus.*	*philippinensis.*	*minimus (varuna).*	*culicifacies.*	*ramsayi.*	*hyrcanus.*	*barbirostris.*	Total collection of the month
Total adult collection from dwelling houses.	994	2,307	3,105	795	683	55	10	150	149	4	8,252
Total adult collection from cattle-sheds.	258	287	1,379	223	23	8	2	75	64	4	2,323

We did not, however, make any collection of mosquitoes from cow-sheds at Birnagar during 1928 and 1929, and following Dr. Sur's advice we sent him mosquitoes caught in dwelling houses only. In some cases cow-sheds form part of dwelling houses. Enquiries made of the inmates of such houses elicit the important information that as night advances mosquitoes from cow-sheds move to the living rooms. No observation has been made as to what proportion actually does so. Almost every family at Birnagar keeps cows and there are 2,000 cows at Birnagar, i.e., one per head of population.

From our findings at Birnagar we suspect that *philippinensis* has the habit of frequenting dwelling houses more at night-time than during the day, but this requires corroboration by further observation. The following statement is interesting:—

STATEMENT XIII.

Comparative statement of the prevalence of species in the day and night-time at Birnagar during the fever season, July to November 1929.

Species.	Day collections.	Percentage.	Night collections.	Percentage.
A. fuliginosus	896	40	385	46·7
A. pallidus	278	12·4	109	13
A. philippinensis	89	4	71	8·6
*A. rossi-vagus**	188	8·38	62	7·4
A. hyrcanus var. *nigerrimus* ..	53	2·36	32	3·8
A. minimus var. *varuna* ..	25	1	6	0·7
A. ramsayi	711	31·7	159	19
A. barbirostris	2	0·08	0	..
TOTAL ..	2,242	..	824	..

* Includes *A. subpictus* and *A. vagus.*

The circumstantial evidence in the two instances cited above is also in favour of incriminating *philippinensis* as a carrier species in the Nadia District. Dr. G. C. Ramsay writes to say that he found this species to feed chiefly on cow's blood in Assam.

As regards infectivity, Dr. Ramsay dissected 5,000 and Dr. Strickland 2,410 specimens of *philippinensis* in Cachar, Assam,* but none of them found a single specimen to be infected. Strickland (1929) comments as follows:—

'The negative infective rate of *philippinensis* based on the dissection of 2,410 specimens must now be noted, for Sur in Bengal has recently (1928) reported finding 3·1 per cent out of 223 specimens naturally infected. It is difficult to suggest an explanation of the discrepancy between his results and that shown in Table I (not printed). His observations were carried on during October and November; those of this survey during April to November, the climate of Cachar being very similar to Bengal at corresponding periods; and while the spleen-indices were over 90 per cent, yet ours were from estates where in 1923 I had found the spleen-index of 373 children to be about 72 per cent. This very important matter needs elucidation.'

On my requesting him to suggest a suitable method for the elucidation of this problem Dr. Strickland replies as follows:—

'The variations reported in the infectivity of Anopheline species are rather disconcerting.... Variations ought of course to be expected from locality to locality or in one locality from season to season (true variations) and then there is the variations due to random sampling (false variation). To determine the importance of these factors might need a very extended research. I have myself proposals for such a research but there is room for many working on the same subject from different points of view.

'Dr. Sur's work could be confirmed by another working under similar conditions. On the other hand his results might be accepted as a working hypothesis by you and their truth demonstrated or otherwise by the results of an anti-*philippinensis* campaign.... '

Major J. A. Sinton, Director, Malaria Survey of India, to whom the matter was referred for elucidation, writes:—

'Regarding *A. philippinensis* it is possible for the feeding habits of a species to differ in different localities, and also for a species to play a considerable part in the transmission of malaria in one locality and not in another, depending on the local conditions.'

In this connection I quote the following opinion expressed by Sir Ronald Ross in his book on 'Studies on Malaria.'

'......years of local observation are required to fix the blame adequately on a species. Even different strains of the same species seem to differ as to their malaria-bearing capacity; and the subject is continuing to receive close scientific attention.'

---

* Ramsay's figures include those given by Strickland.—Ed.

It is interesting to note that Dr. G. C. Ramsay has some observations to make in support of this theory (Ramsay, 1930). He writes as follows:—

'Perhaps some of the most important points, which have emerged from the research, are our negative findings, especially with species such as *A. maculatus* and *A. aconitus*, which are regarded as dangerous natural carriers of malaria in the Federated Malay States.' He again questions—'Is zoophilism the factor in Cachar, which prevents species, which are known to be efficient carriers of malaria in Nature elsewhere, from doing likewise in this district? Or are there other factors?' I have already said that almost every family at Birnagar keeps cows but this does not give them any immunity from the attack of *Anopheles philippinensis*. The principal factor in non-infectivity must be something else than zoophilism.

Yet another view is forthcoming from Dr. G. Bose, D.SC., M.B., Chief Medical Adviser to the Mandali, who was consulted on the point:

'The discrepancy observed as regards infectivity of mosquitoes may be ultimately traced to the presence or absence of certain types of food materials available in different localities.

'The susceptibility of a human being, for instance, towards pyorrhœal infection is very much increased by the absence of certain vitamines in food. It may be that because of a peculiar food deficiency the *philippinensis* in Bengal is liable to get infected while the same species in Assam owing to a proper food supply is immune from infection. The problem requires careful investigation.'

There is also another aspect of the problem to which I want to lay stress. We know that *pallidus* was separated from *fuliginosus* and *philippinensis* from *pallidus* only in 1927, and it seems to me highly probable that yet another species may be separated from *philippinensis* which would settle all discrepancies. It should be remembered that *fuliginosus* was held to be the culprit in Bengal by certain specialists before *philippinensis* was separated from it. The bi-modal character of the *philippinensis* curves during 1928 at Birnagar and Krishnagar also offers some ground for suspicion that two species are mixed up in the group identified at present as *philippinensis*. It is possible, however, that the similarity in the two curves is accidental and due to other factors. As I have said before, all species of Anopheline mosquitoes prevalent at Birnagar (other than *rossi-vagus* and *barbirostris*) show a tendency to increase in number in the rainy season till they reach their maximum in October or November. Consequently the fall in the curve in October should be accepted with caution. It seems to me that it is worth while for specialists to study the Assam and Birnagar specimens of *philippinensis*, more particularly the infected ones. It is a matter of great satisfaction that Dr. Sur has kindly agreed to take up this important investigation at my suggestion. It is also understood that a further study is also being carried on by Colonel S. R. Christophers upon the material available in the collection at Kasauli. If my conjecture eventually turns out to be correct, it will probably be seen that there

are only a small number of the Assam type of *philippinensis* in the Nadia District as is evidenced from the figure under cattle-sheds in Statement XII. Whether any new species are eventually separated from *philippinensis* or not, the result cannot affect our malaria control work, and if any new species is discovered later the only difference will be that our work will probably be further narrowed down as a result of re-survey of the present breeding grounds of *philippinensis*.

Practical application of the findings.

The result of our survey clearly demonstrates that *Anopheles philippinensis* is the carrier species at Birnagar, and although this information will undoubtedly be of great importance in modifying our system of control to a large extent, it does not unfortunately solve our problem entirely. The examination of the breeding grounds throws considerable light on the habits of the local Anopheline species which do not tally with those of the species found in Assam and the Federated Malay States. In the two latter regions species are said to select different breeding grounds which makes it possible for workers to confine oiling operations to those pools where carrier species are only found. At Birnagar, and perhaps in other parts of Bengal, several species are frequently to be found breeding in the same pool Considerable variations are however noticed regarding their breeding as will be seen from the extract from a record of one of the breeding pools:

Tank No. 75, Purana Dighi.

1929			
4th August	..	..	*fuliginosus*
11th "	..	..	*fuliginosus*
			subpictus.
			hyrcanus.
			pallidus.
			philippinensis.
25th "	..	..	*fuliginosus.*
			hyrcanus
1st September	..	..	*fuliginosus.*
			hyrcanus
			pallidus.
14th "	..	..	*hyrcanus.*
			pallidus.
			philippinensis.
29th "	..	..	*fuliginosus.*

At first sight this state of affairs seems to be bewildering, but a close scrutiny shows that there is room for discrimination, and that out of apparent chaos some order may be evolved. We are however mainly concerned with the habits of *philippinensis*. If we group the larval findings under each month

the apparent variations in the breeding of *philippinensis* in many instances disappear or are greatly reduced, as will be seen from the statement below:—

STATEMENT XIV.

Tank No. 75, Purana Dighi.

1929.	
January	Not examined.
February	*pallidus.* *philippinensis.*
March	Not examined.
April	*pallidus.*
May	*pallidus.* *philippinensis.*
June	Dry.
July	*subpictus.*
August	*fuliginosus.* *pallidus.* *subpictus.* *philippinensis.* *hyrcanus.*
September	*pallidus.* *philippinensis.* *hyrcanus.* *fuliginosus.*
October	Not examined.
November	*pallidus.* *philippinensis.* *hyrcanus.*
December	*minimus* var. *varuna.*

Tank No. 125, Dutta Pokur.

1929.	
January and February	Not examined.
March	*philippinensis.* *fuliginosus.* *hyrcanus.* *pallidus.*
April	*philippinensis.* *hyrcanus.*
May	*philippinensis.* *ramsayi.*
June	*ramsayi.* *fuliginosus.* *philippinensis.*
July	*hyrcanus.* *subpictus.* *philippinensis.*
August	*philippinensis.* *hyrcanus.*
September	*barbirostris.* *philippinensis.*
October to December	Not examined.

1930.	
January	*fuliginosus.*
	hyrcanus.
	barbirostris.
February	*hyrcanus.*
	fuliginosus.
	ramsayi.
March	*philippinensis.*
	pallidus.
	hyrcanus.

Tank No. 170, *Chouka.*

January	*philippinensis.*
	ramsayi.
	hyrcanus.
February	Not examined.
March	*philippinensis.*
	hyrcanus.
	minimus var. *varuna.*
	ramsayi.
April	*philippinensis.*
	minimus var. *varuna.*
	subpictus.
May	*subpictus.*
	philippinensis.
	fuliginosus.
June	*subpictus.*
July	Not examined.
August	*hyrcanus.*
	minimus var. *varuna.*
	philippinensis.
September	*hyrcanus.*
	philippinensis.
	barbirostris.
	fuliginosus.
October	*fuliginosus.*
November	Not examined.
December	*fuliginosus.*

There are numerous pools and certain tanks where *philippinensis* larvæ have not been found at all, notwithstanding careful examination.

Our rules require that collections of larvæ from a tank or pool should be made from the surface without much disturbing the water, and that the dipping should be made all along the water edges at certain intervals according to its size and condition. In certain cases the entire water surface has to be examined. In actual practice the work sarkar and the coolies, particularly when the supervisor is absent, may not follow this rule strictly. In all such work we cannot altogether avoid bad sampling, and when the collection is made more

than once a month from the same breeding places we get more accurate findings. Possibly the absence of *philippinensis* larvæ in certain months from the tanks named in Statement XIV may in most instances be due to bad sampling, or to their loss by disintegration due to the conditions of transit to Calcutta by rail. In a good many cases the variations in the breeding of *philippinensis* in permanent reservoirs of water, as noticed in our breeding frequency list, may be more artificial than real.

We may classify the breeding grounds of *philippinensis* in accordance with this list as follows:—

I. PERMANENT POOLS.

(*a*) Where *philippinensis* larvæ were found periodically in all the three seasons, viz., winter, summer and rainy;

(*b*) Where *philippinensis* larvæ were found in one or two seasons only in the year;

(*c*) Where *philippinensis* larvæ were found once in one or two years.

II. TEMPORARY POOLS.

(*d*) Where *philippinensis* larvæ were found during the rains;

(*e*) Where *philippinensis* larvæ were found in other seasons as well owing to the water still existing in the winter and early summer, or fresh accumulation from winter or spring showers.

If the surmise made above is generally held to be correct, many breeding grounds now falling under item (*b*) will properly be included under (*a*). Where conditions mentioned in (*b*) exist it will be necessary to make a further study of the habits of *philippinensis*. In some cases the seasonal breeding of this species may be found to synchronize with the growth of certain kinds of vegetation in tanks. As regards (*c*) it seems to me that mosquitoes out of sheer necessity are sometimes compelled to lay eggs in such collections of water when they are at some distance from their favourite breeding pools. Such cases are few in number. No remarks are called for in regard to (*d*) and (*e*). From the actual condition of all these breeding places we know that *philippinensis* loves to breed in large tanks and large shallow pools, depressions and marshes which are covered with vegetation such as tall grasses, *Pistia stratiotes, Nelumbium speciosum, Vallisneria spiralis, Limnanthemum indicum, Nymphaea rubra*. A botanical survey of the breeding grounds of *philippinensis* at Birnagar is under contemplation.

As the habits of *philippinensis* have been studied at Birnagar for a short period only, we are unable to say yet if it changes its breeding grounds, and if so under what conditions.

It seems necessary therefore that the habits of this species should be more closely studied on the spot in order to elucidate the several points mentioned above. Krishnagar and Calcutta are too far away for the purpose. We are grateful to Dr. C. A. Bentley, Director of Public Health, Bengal, for the valuable help rendered by him for the solution of our problem. It is extremely

desirable in the interest of the continuity of the campaign that the problem should be narrowed down as much as possible. It is hoped that the Public Health Department, Bengal, will give us such facilities as may be necessary for carrying out a more detailed examination of the problem locally.

With regard to the question whether an all-species campaign is better than one directed solely against the disease-bearing Anopheline mosquitoes, our experience shows that so far as Bengal is concerned there can be no choice in the matter. We attempted the first at Birnagar but failed to give full effect to it. In the beginning there was vehement opposition to the oiling of tanks used for bathing and other domestic purposes, with the result that several large tanks were left out from the scope of our operation. Subsequent investigation showed that we left out important breeding grounds of *philippinensis*. We lately overcame this opposition by a persistent house-to-house propaganda, resulting in an extension of our work which necessitated an expansion of staff and increased consumption of larvicides. By excluding the Chaka Bil and certain pools on the outskirts of the town, which were subsequently found to contain *philippinensis* larvæ, we managed to meet all our expenses during the rainy season of 1929, but we were faced with a breakdown early in 1930 for want of funds, which compelled us to curtail oiling operations during the dry season and the suspension of some of the trained staff at least temporarily. With the determination of *philippinensis* as the carrier species of Birnagar and the location of its breeding grounds, adequate treatment of the latter throughout the year becomes the first charge on our budget estimate of larvicides. This means that when funds become short we must leave out from our scope of oiling pools in the heart of the town which are not the breeding grounds of this species. The Chaka Bil, which is outside our municipal limits but adjacent to it, has recently been found to be a breeding ground of *philippinensis*. If as a result of a more detailed survey it is found to be a source of danger to Birnagar, this big sheet of water will have to be included in our scheme of operations. An extension of work outside our border line in some cases may thus be forced upon us. Paucity of funds compels us to restrict our campaign to carrier species only.

As our knowledge regarding the habits of *philippinensis* is limited there is no alternative but to include in our scope of treatment all its breeding grounds as classified above, except those falling under (*c*). The figures so far available seem to indicate that the reduction of *philippinensis* is being steadily effected at Birnagar. The figures during the worst malarial months, viz., September to November of 1928 and 1929 are given below:—

Year.	All species including *philippinensis*.	*philippinensis* only.	Percentage.
1928 ..	2,294	487	21
1929 ..	2,615	104	4

The collection of mosquitoes during 1930 was undertaken on a large scale, and included mosquitoes both from dwelling houses and cow-sheds at Birnagar. The identifications were kindly undertaken not only by the Public Health Department, Bengal, but by the Malaria Survey of India and another well-known Calcutta Institution. Figures from one of these laboratories are still due, but from what have been received from two others it appears that there has been a further reduction of *philippinensis* mosquitoes during 1930.

It may be that this reduction of *philippinensis* has been due to factors other than the anti-*philippinensis* campaign, but the position is likely to be cleared up in the next few years. The figures indicate only a reduction in its prevalence in dwelling houses, and we have no means of ascertaining what reduction has actually taken place elsewhere. Apparently we must reach a certain limit in this reduction before we can expect any substantial decrease in fever cases. In my annual report on Malaria Control at Birnagar for 1928-29, I stated that the anti-larval measures at Birnagar up to that year had not produced any tangible results, and that the reduction in splenic index in that town had been due to our effective quinine campaign. The figures of malarial incidence at Birnagar during the next few years will therefore be watched with interest.

If the figures quoted above correctly represent the progress of the anti-*philippinensis* campaign, the high percentage of this species found during the worst malarial months of 1928 indicates how a general Anopheline campaign, carried on under limitations and without any knowledge of the carrier species to be tackled, is likely to be inadequate. I have already discussed this point in some detail above. Although we have never attempted any anti-adult campaign, certain malarialogists consider this to be an important auxiliary to malaria control. The *philippinensis* figures for 1928 suggest that a general destruction of Anopheline mosquitoes may be helpful so long as we can collect a good number of carrier species. But when its number becomes small as in 1929 and 1930 a general attack on adults is likely to fall on the non-carriers.

I may mention that *philippinensis* lays eggs in all the breeding pools of *minimus* var. *varuna* and *aconitus* and also in several pools where other species breed. Our campaign is, therefore, automatically directed not only against *philippinensis* but also against *minimus* var. *varuna* and *aconitus*.

It seems to me that in rural Bengal with its bils, marshes, canals, tanks, pools and depressions, it is an impossible enterprise to carry on a general anti-mosquito campaign which is bound to end in failure mainly on account of cost. The recent introduction of powerful rotary blowers for applying paris green has greatly facilitated our work, and an extension of work outside our border line for dealing with carrier species only may be possible. The Calcutta session of the Far Eastern Association of Tropical Medicine rightly laid down that for wide rural areas the first step in the control of malaria is adequate research, so that the conditions present may be ascertained and the best method of control under the particular circumstances determined as a result of such

research. It cannot be otherwise at Birnagar which presents all the features of a rural area. It is through field investigation and research that we can hope to solve the problem not only at Birnagar but in the whole of Bengal.

SUMMARY.

The mosquito survey carried out at Birnagar during the years 1927 to 1929 shows that *Anopheles philippinensis* is the principal carrier of malaria at Birnagar and that it prefers to feed on human blood rather than cow's blood. The discrepancies found in respect of infectivity and habits between the Assam and Bengal specimens are discussed, and an attempt has been made to solve them.

Records of certain breeding pools have been quoted to show that there is some consistency in the breeding habits of *philippinensis,* and that species campaign is possible in Bengal. The need of research work on the spot is emphasized for the elucidation of certain characteristics of its habits, which can only be done if special facilities are offered to the Mandali by the Public Health Department, Bengal.

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SUPPLEMENTARY FINDINGS.

A PROBLEM SOLVED.

After the above report was set in type we have been favoured with the opinion of Col. S. R. Christophers on the proper identification of the species described therein as *A. minimus* var. *varuna.* I already stated in my report that we recently separated *A. aconitus* from *A. minimus* var. *varuna.* This was done with the unanimous consent of the entomologists concerned. But as we had our doubts about the grouping under *A. minimus* var. *varuna* of the other *minimus*-like forms of mosquitoes, we sent specimens of all the varieties to the Malaria Survey of India, who submitted them to Col. Christophers for his critical opinion. After a careful examination of the material sent by us, Col. Christophers is satisfied that 'all the *minimus*-like forms are *A. aconitus.*' He further writes: 'Your specimens are not *A. varuna*' and gives reasons for his opinion. As he is publishing a short note on the identification of these forms I have not thought it necessary to enter into a discussion here.

I must express my gratitude to Col. Christophers for solving one of our knotty problems. In view of his decision we must assume that all the specimens of mosquitoes grouped under *A. minimus* var. *varuna* should now be read as *A. aconitus.* It now seems clear that we have no species of *A. minimus* nor its variant *varuna* at Birnagar.

As regards the prevalence and habits of *A. aconitus* (described as *A. minimus* var. *varuna*) I already stated in my report that we found the adults in very small numbers in dwelling houses and their larvæ in small quantity in a limited number of pools. In the course of our collections of mosquitoes from cow-sheds we discovered *A. aconitus* in large numbers in some of them in the winter of 1930-31. There seems no doubt therefore that *A. aconitus* avoids human habitation and shows an extraordinary liking for bovine blood. The favourite breeding ground of this species was also located recently outside Birnagar in the eastern portion of Chaka Bil where water is shallow and grasses grow abundantly. The habits of this species at Birnagar tally with those described by Dr. Ramsay in respect of the Assam specimens.

PLATE VI.

Fig 1

Fig 2

Explanation of Plate VI.

Fig. 1. Purana Dighi. Area 12 acres. Note the tall grasses which abound in the tank. Breeding ground of *A. philippinensis* and certain other species.

Major J. A. Sinton and Dr. de Buen of the League of Nations' Malaria Commission examining the effect of soluble cresol on this breeding ground. Out of 90 dips three Anopheline larvæ were found.

„ 2. The League of Nations' Malaria Commission noting down the results of experiments made in the same tank with different kinds of larvicides. The Commission's suggestion for using paris green by rotary blowers was adopted after proper trial.

EXPLANATION OF PLATE VII.

Fig. 3. Khan Dighi. Area 7 acres. Note that half the surface is covered with *Nelumbium speciosum*. Here *A. philippinensis* larvæ were found along with those of *A. hyrcanus* and a few other species. Paris green applied by rotary blowers was found to be the easiest way of dealing with this tank.

" 4. Baromeshey Canal. Connects the Chaka Bil with the river Churni. A photograph of the demonstration of the use of paris green by hand and also by a hand blower. It may be noted that hand blowers have since been replaced by rotary blowers with great success.

PLATE VII.

Fig 3

Fig 4

Records of the Malaria Survey of India, Vol. II, No. 2, June, 1931.

THE DISTRIBUTION OF ANOPHELINE MOSQUITOES IN INDIA AND CEYLON : ADDITIONAL RECORDS, 1926—1930.

BY

MAJOR G. COVELL, M.D., D.P.H., I.M.S ,
Assistant Director, Malaria Survey of India.

[February 14, 1931.]

INTRODUCTION.

THE existing records of distribution of the anopheline mosquitoes of India and Ceylon up to about the middle of the year 1926 were summarized in *Indian Medical Research Memoir No.* 5 (1927). The data from which these were drawn consisted of the records of the Central Malaria Bureau, India, published works, and MSS. or other reports in the offices of the Directors of Public Health of the various provinces of India. A large number of additional records have been received at the Central Malaria Bureau or have appeared in various published or unpublished reports of surveys since the Memoir appeared. The object of the present paper is to bring the information given in the Memoir up to date.

Only *new* records are here given; in cases where a species has already been cited in Memoir No. 5 as occurring in a particular locality, additional records for that species from the same place are omitted.

The species of anophelines and the divisions, subdivisions and localities from which they have been recorded are placed in alphabetical order; otherwise the arrangement of the data is the same as that followed in Memoir No. 5. Figures preceded by the letters **MB** or **KL** refer to entries in the registers at the Central Malaria Bureau. All other figures refer to reports and articles cited in the List of References at the end of the paper.

aconitus.

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Goalpara Dist.,** Kuchugaon, **MB-26; Kamrup Dist.,** Gauhati, **MB-165-29; Lakhimpur Dist., 93h; Sibsagar Dist.,** Mariani, **148; Sylhet Dist., 93h.**

BENGAL.

Backergunge Dist., Barisal, **93f; Bogra Dist.,** Bogra, **93f; Burdwan Dist.,** Burdwan, **93f,** Kalna, **93f,** Memari, **93f; Chittagong Dist.,** Chittagong, **93f; Dacca Dist.,** Dacca, **93f, MB-24-30,** Manikganj, **93f; Darjeeling Dist.,** Marianbari, **129d; Dinajpur Dist.,** Parbatipur, **MB-3-29; Faridpur Dist.,** Faridpur, **93f; Hooghly Dist.,** Hooghly, **93f; Howrah Dist.,** Santragachi, **MB-23-29; Jessore Dist.,** Bongaon, **93f, MB-324-30; Khulna Dist.,** Khulna, **93f; Malda Dist.,** Malda, **93f; Nadia Dist.,** Birnagar, **MB-94-30, MB-342-30,** Khoksa, **MB-11-30,** Krishnagar, **93f; Noakhali Dist.,** Noakhali, **93f; Tippera Dist.,** Comilla, **93f; 24-Parganas Dist.,** Kanchrapara, **MB-322-30.**

BIHAR.

Purnea Dist., Katihar, **MB-3-29.**

BURMA (LOWER).

Salween Dist., Papun, **127a.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106e; N. Hsenwi State** (N. Shan States), Lashio, **106d; Upper Chindwin Dist.,** Mawlaik, **127b; Yaung Hwe State** (S. Shan States), **25a,** Shwenyaung, **128.**

CENTRAL PROVINCES (WEST).

Jubbulpore Dist., Jubbulpore, **MB-250-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Jeypore, **MB-386-30,** Vizagapatam, **MB-27.**

MALABAR.

Travancore State, 146.

MYSORE STATE.

Bangalore Dist., Bangalore, **144; Chitaldrug Dist.,** Hiriyur, **144; Kadur Dist.,** Mudgere, **144; Mysore Dist.,** Nagenhalli, **144.**

UNITED PROVINCES (EAST).

Gorakhpur Dist., Gorakhpur, **MB-28.**

aitkenii.

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Sibsagar Dist.,** Mariani, **148.**

BENGAL.

Darjeeling Dist., Marianbari, **129c.**

BURMA (UPPER).

N. Hsenwi State (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30.**

KONKAN.

N. Kanara Dist., Ramangali, **129g.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Illsamuthi, **111.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Mettupalaiyam, **129a; N. Arcot Dist.,** Tirupati, **130a.**

MALABAR.

Coorg Province, 122, Mercara, **129g,** Somwarpet, **54d,** Verajpet, **54d; Malabar Dist.,** Palghat, **130e.**

MYSORE STATE.

Kadur Dist., Mudgere, **144.**

aitkenii var. bengalensis.

BENGAL.

Darjeeling Dist., Marianbari, **129g,** Sukna, **129g.**

annandalei.

ASSAM.

Cachar Dist., Labac, **MB-92-28.**

annandalei var. interruptus.

BENGAL.

Darjeeling Dist., Sukna, **129e.**

barbirostris.

ASSAM.

Cachar Dist., Labac, **MB-26; Darrang Dist., 93h; Goalpara Dist., 14a,** Kuchugaon, **MB-26; Kamrup Dist.,** Gauhati, **MB-74-29; Sibsagar Dist.,** Mariani, **148.**

BENGAL.

Backergunge Dist., Barisal, **93f; Bankura Dist.,** Bankura, **93f; Bogra Dist., 14a,** Bogra, **93f; Burdwan Dist.,** Burdwan, **93f,** Kalna, **93f,** Memari, **93f,** Nabadwip, **93f; Dacca Dist.,** Dacca, **93f,** Manikganj, **93f; Darjeeling Dist.,** Marianbari, **129c; Faridpur Dist., 14a,** Faridpur, **93f; Hooghly Dist.,** Hooghly, **93f; Howrah Dist.,** Belur, **93f; Jalpaiguri Dist.,** Jalpaiguri, **93f,** Madarihat, **95d; Jessore Dist.,** Bongaon, **93f,** Jessore, **93f; Khulna Dist., 14a,** Khulna, **93f; Malda Dist., 14a,** Malda, **93f; Midnapur Dist.,** Midnapur, **93f; Mymensingh Dist.,** Mymensingh, **93f; Murshidabad Dist.,** Berhampore, **93f; Nadia Dist.,** Birnagar, **MB-270-30,** Khoksa, **MB-322-30,** Krishnagar, **93f, 95e; Noakhali Dist.,** Noakhali, **93f; Pabna Dist., 14a,** Pabna, **93f; Rangpur Dist., 14a,** Rangpur, **93f; Tippera Dist.,** Comilla, **93f; 24-Parganas Dist., 14a,** Baranagar, **39g,** Baraset, **39g,** Baruigar, **39g,** Baruipur, **MB-26,** Behala, **39g,** Dum-Dum, **39g,** Khandah, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BIHAR.

Bhagalpur Dist., Bhagalpur, **114a; Purnea Dist.,** Purnea, **MB-316-30.**

BOMBAY DECCAN.

Poona Dist., Paud, **MB-225-29.**

BURMA (LOWER).

Rangoon, 106g; Salween Dist., Papun, **MB-26, 127a.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c; Hsipaw State** (N. Shan States), Hsipaw, **106e; Minbu Dist.,** Mezali, **106h,** Pwinbyu, **106i; N. Hsenwi State** (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127b; Yaung Hwe State** (S. Shan States), Fort Stedman, **25a,** Shwenyaung, **128.**

CHOTA NAGPUR.

Hazaribagh Dist., Hazaribagh, **114; Singhbhum Dist.,** Dangoaposi, **80i.**

GUJARAT.

Baroda State, Vyara, **MB-215-30.**

KONKAN.

Kolaba Dist., Karjat, **MB-3-30.**

MADRAS COAST (NORTH).

Godaveri Dist., Yanaon, **116; Vizagapatam Dist.,** Jeypore, **MB-386-30,** Lammasingi, **135,** Peddavalasa, **135.**

MADRAS DECCAN.

Anantapur Dist., Anantapur, **MB-26; Bellary Dist.,** Kummataravu, **130k; Cuddapah Dist.,** Talamanchipatnam, **130i; Kurnool Dist.,** Nandyal, **130t.**

MADRAS (SOUTH-EAST).

N. Arcot Dist., Tirumalai Hills, **130b,** Tirupati, **130a.**

MALABAR.

Malabar Dist., Anayarkuni, **130d,** Palghat, **130e; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30, 144; Mysore Dist.,** Nagenhalli, **144.**

PUNJAB (EAST & NORTH).

Karnal Dist., Karnal, **MB-28.**

UNITED PROVINCES (EAST).

Cawnpore Dist., Cawnpore, **MB-220-30.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Rudarpur, **118.**

barbirostris var. **ahomi.**

ASSAM.

Lakhimpur Dist., 117.

culicifacies.

ASSAM.

Cachar Dist., Labac, **MB-27; Goalpara Dist., 14a; Lakhimpur Dist., 93h; Sibsagar Dist.,** Mariani, **148.**

BALUCHISTAN.

Loralai Dist., Loralai, **MB-146-29; Quetta-Pishin Dist.,** Chaman, **MB-28,** Pishin, **MB-49-29.**

BENGAL.

Birbhum Dist., Suri, **93f; Bogra Dist., 14a; Burdwan Dist.,** Asansol, **93f; Dacca Dist.,** Dacca, **MB-24-30; Darjeeling Dist., 14a,** Marianbari, **129b; Jalpaiguri Dist.,** Jalpaiguri, **93f,** Madarihat, **95d; Jessore Dist., 14a; Khulna Dist., 14a; Malda Dist.,** Malda, **93f; Murshidabad Dist.,** Bazar Sohu, **93f,** Berhampore, **93f; Nadia Dist.,** Birnagar, **140,** Krishnagar, **95e; Pabna Dist.,**

14a; Rajshahi Dist., 14a; Rangpur Dist., 14a; 24-Parganas Dist., Baranagar **39g,** Behala, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BIHAR.

Bhagalpur Dist., Bhagalpur, **114a; Gaya Dist.,** Aurangabad, **KL-5-29,** Gaya, **MB-28,** Nawada, **KL-72-28,** Tekari, **MB-8-30,** Wazirganj, **KL-72-28.**

BOMBAY DECCAN.

Poona Dist., Jejuri, **MB-225-29,** Lonavla, **MB-357-30,** Paud, **MB-225-29,** Sangwi, **MB-225-29; Satara Dist.,** Lonand, **MB-225-29,** Padegaon, **MB-225-29; Sholapur Dist.,** Kurduvadi, **MB-397-30.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c; Hsipaw State** (N. Shan States), Hsipaw, **106e; Mandalay Dist.,** Maymyo, **MB-194-30, 138; Minbu Dist.,** Mezali, **106h,** Pwinbyu, **106i; Myitkyina Dist.,** Myitkyina, **120,** Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **106d; Thayetmyo Dist., 25a; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL INDIA (EAST).

Rewah State, Sutna, **MB-187-30.**

CENTRAL INDIA (WEST).

Bhopal State, Sehore, **MB-26; Gwalior State,** Bhind, **MB-26.**

CHOTA NAGPUR.

Hazaribagh Dist., Bagodar, **KL-5-29,** Champara, **MB-28,** Damodar Valley, **KL-5-29,** Hazaribagh, **114,** Mirzaganj, **KL-72-28; Ranchi Dist.,** Namkum, **MB-107-27; Singhbhum Dist.,** Dangoaposi, **80i.**

GUJARAT.

Baroda State, Baroda, **136,** Navsari, **MB-266-30,** Vyara, **MB-197-30; Gohelwar** (Kathiawar), Bhavnagar, **MB-287-30; Kalar** (Kathiawar), Rajkot, **KL-3-29; Jhalawar** (Kathiawar), Wadhwan, **MB-287-30; Sorath** (Kathiawar), Junagadh, **MB-287-30,** Sasan, **83d.**

KONKAN.

Kolaba Dist., Karjat, **MB-21-29.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y,** Humma, **130w; Nellore Dist.,** Duttalur, **47b,** Mopad, **47a,** Udayagiri, **47c; Vizagapatam Dist.,** Bimilipatam, **40d,** Krishnadevipet, **135.**

MADRAS DECCAN.

Bellary Dist., Desanur, **130n,** Kenchanaguddam, **130n,** Ramandrug, **129a,** Siriguppa, **130n; Cuddapah Dist.,** Janganapalli, **130i,** Talámanchipatnam, **130i; Kurnool Dist.,** Koilkuntla, **130s,** Kurnool, **130r,** Nandyal, **130t,** Owk Union, **130q.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Coimbatore, **129a,** Kollegal, **130g,** Mettupalaiyam, **129a; N. Arcot Dist.,** Tirupati, **130a; Salem Dist.,** Mettur, **126.**

MALABAR.

Coorg Province, Verajpet, **54d; Malabar Dist.,** Palghat, **130e; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Chittaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Kohat Dist., Khushalghar, **83a; Peshawar Dist.,** Dargai, **MB-128-29,** Mardan, **MB-382-30,** Risalpur, **MB-237-30,** Shagai, **MB-53-29; Swat Territory,** Chakdara, **MB-113-29,** Malakand, **MB-53-29.**

ORISSA.

Mayurbhanj State, Badampahar, **MB-13-29; Patna State,** Titalagarh, **MB-15-29.**

PUNJAB (EAST & NORTH).

Gujranwala Dist., Khanki, **83i; Gujrat Dist.,** Kathala, **83i; Gurdaspur Dist.,** Bakloh, **MB-82-29; Patiala State,** Patiala, **MB-279-30,** Pinjaur, **MB-63-31; Sialkot Dist.,** Marala, **83i.**

PUNJAB (SOUTH-WEST).

Multan Dist., Multan, **MB-60-27.**

RAJPUTANA (EAST).

Udaipur State, Udaipur, **MB-26.**

SIND.

Hyderabad Dist., Badin, **112c,** Dero Mahbat, **112c,** Guni, **112c,** Tando Bago, **MB-344-30; Karachi Dist.,** Karachi, **MB-27; Larkana Dist.,** Larkana, **MB-27,** Walid, **112d; Nawabshah Dist., MB-29; Sukkur Dist.,** Sukkur, **MB-27, Shikarpur, 112a; Thar and Parkar Dist.,** Digri, **112b,** Jamesabad, **112b,** Mirpur Khas, **112b; Upper Sind Frontier Dist.,** Jacobabad, **MB-29.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Banbassa, **MB-294-30,** Banda, **MB-294-30,** Rudarpur, **118; Saharanpur Dist.,** Hardwar, **131.**

WAZIRISTAN.

Bannu Area, Mari Indus, **MB-26,** Mir Ali (nr. Idak), **129b; Derajat Area,** Wana, **MB-53-30.**

culiciformis.

KONKAN.

Goa, Valpoi, **KL-117-28.**

dthali.

BALUCHISTAN.

Zhob Dist., Fort Sandeman, **MB-169-29, MB-96-30.**

PUNJAB (EAST & NORTH).

Jhelum Dist., Kallar Kahar (Chakwal Tehsil), **143.**

WAZIRISTAN.

Bannu Area, Mir Ali (nr. Idak), **129b,** Razmak, **MB-156-27; Derajat Area,** Khirgi, **MB-26,** Manzai, **MB-26.**

fuliginosus.

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Goalpara Dist., 14a,** Kuchugaon, **MB-26; Kamrup Dist.,** Gauhati, **MB-74-29; Sibsagar Dist.,** Mariani, **148.**

BENGAL.

Backergunge Dist., Barisal, **93f; Birbhum Dist.,** Bolpur, **93f,** Suri, **93f; Bogra Dist., 14a,** Bogra, **93f; Burdwan Dist.,** Asansol, **93f,** Burdwan, **93f,** Kalna, **93f,** Memari, **93f,** Nabadwip, **93f; Chittagong Dist.,** Chittagong, **93f; Cooch Behar State, 14a; Dacca Dist.,** Dacca, **93f,** Manikganj, **93f; Darjeeling Dist.,** Marianbari, **129c,** Siliguri, **93f; Dinajpur Dist.,** Parbatipur, **MB-3-29; Faridpur Dist., 14a,** Faridpur, **93f; Hooghly Dist.,** Hooghly, **93f; Howrah Dist.,** Belur, **93f; Jalpaiguri Dist.,** Jalpaiguri, **93f,** Saontalpur, **KL-57-28; Jessore Dist., 14a,** Bongaon, **MB-325-30; Khulna Dist., 14a; Malda Dist., 14a,** Malda, **93f; Midnapur Dist.,** Midnapur, **93f; Murshidabad Dist.,** Bazar Sohu, **93f,** Berhampore, **93f; Mymensingh Dist.,** Mymensingh, **93f; Nadia Dist.,** Birnagar, **MB-240-30,** Khoksa, **MB-322-30,** Krishnagar, **95e; Noakhali Dist.,** Noakhali, **93f; Pabna Dist.,** Pabna, **93f; Rajshahi Dist., 14a; Rangpur Dist.,** Rangpur, **93f,** Saidpur, **MB-3-29; Tippera Dist.,** Comilla, **93f; 24-Parganas**

Dist., Baranagar, **39g,** Baraset, **39g,** Baruigar, **39g,** Baruipur, **39g,** Behala, **39g,** Dum-Dum, **39g,** Khandah, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BIHAR.

Bhagalpur Dist., Bhagalpur, **114a; Gaya Dist.,** Aurangabad, **KL-5-29,** Newada, **KL-72-28,** Tekari, **KL-72-28; Purnea Dist.,** Bhogaon, **25a,** Katihar, **MB-3-29,** Kierpur, **25a,** Purnea, **MB-281-30; Santal Parganas Dist.,** Madhupur, **25a.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26; Poona Dist.,** Kirkee, **MB-11-30,** Lonavla, **MB-6-29,** Paud, **MB-225-29; Satara Dist.,** Lonand, **MB-225-29.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106e; Minbu Dist.,** Mezali, **106h; Myitkyina Dist.,** Myitkyina, **120,** Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30; Upper Chindwin Dist.,** Mawlaik, **127b; Yaung Hwe State** (S. Shan States), Heho, **25a,** Shwenyaung, **128.**

CENTRAL INDIA (WEST).

Bhopal State, Sehore, **MB-26; Gwalior State,** Neemuch, **MB-199-29.**

CHOTA NAGPUR.

Hazaribagh Dist., Bagoda, **KL-5-29,** Hazaribagh, **114,** Manda, **KL-5-29; Singhbhum Dist.,** Dangoaposi, **80i.**

GUJARAT.

Baroda State, Baroda, **136,** Navsari, **MB-266-30,** Vyara, **MB-215-30; Jhalawar** (Kathiawar), Wadhwan, **83e; Gohelwar** (Kathiawar), Bhavnagar, **83g.**

KONKAN.

Kolaba Dist., Karjat, **MB-3-30.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y,** Humma, **130w; Nellore Dist.,** Duttalur, **47b,** Mopad, **47a,** Udayagiri, **47c; Vizagapatam Dist.,** Bimilipatam, **40d.**

MADRAS DECCAN.

Cuddapah Dist., Cuddapah, **130j,** Talamanchipatnam, **130i; Kurnool Dist.,** Kurnool, **130p,** Nandyal, **130t,** Owk Union, **130q.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Coimbatore, **129a,** Kollegal, **130g; N. Arcot Dist.,** Tirumalai Hills, **130b,** Tirupati, **130a; Salem Dist.,** Mettur, **59d; Tanjore Dist.,** Vedaranniyam, **130c.**

MALABAR.

Coorg Province, 122, 54d.

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Chitral State, Chitral, **MB-225-30; Peshawar Dist.,** Dargai, **MB-128-29,** Landikotal, **MB-180-30; Swat Territory,** Chakdara, **MB-324-30,** Malakand, **MB-53-29.**

ORISSA.

Patna State, Titalagarh, **MB-15-29.**

PUNJAB (EAST & NORTH).

Ambala Dist., Kasauli, **MB-27, MB-285-30; Jullundur Dist.,** Jullundur, **139; Gujranwala Dist.,** Chakanwali, **124,** Khanki, **83i; Patiala State,** Patiala, **MB-279-30; Sialkot Dist.,** Marala, **83i; Simla Dist.,** Sanawar, **MB-122-27.**

PUNJAB (SOUTH-WEST).

Multan Dist., Multan, **139.**

RAJPUTANA (EAST).

Ajmer-Merwara Province, Ajmer, **KL-88-29.**

SIND.

Hyderabad Dist., Tando Bago, **112c.**

UNITED PROVINCES (EAST).

Cawnpore Dist., Cawnpore, **MB-220-30.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Kichcha, **MB-294-30,** Rudarpur, **118; Saharanpur Dist.,** Hardwar, **131.**

WAZIRISTAN.

Bannu Area, Idak, **MB-116-29,** Razmak, **MB-95-30.**

gigas var. **simlensis.**

ASSAM.

Cachar Dist., Labac, **MB-27.**

BENGAL.

Rangpur Dist., Saidpur, **93f.**

N. W. F. P.

Peshawar Dist., Nowshera, **MB-177-27.**

PUNJAB (EAST & NORTH).

Karnal Dist., Karnal, **MB-58-31.**

UNITED PROVINCES (WEST).

Saharanpur Dist., Saharanpur, **MB-27.**

hyrcanus var. **nigerrimus.**

ASSAM.

Cachar Dist., Labac, **MB-27; Goalpara Dist.,** Kuchugaon, **MB-26; Kamrup Dist.,** Gauhati, **MB-74-29; Sibsagar Dist.,** Mariani, **148.**

BENGAL.

Backergunge Dist., Barisal, **93f; Bankura Dist.,** Bankura, **93f; Birbhum Dist.,** Bolpur, **93f,** Suri, **93f; Bogra Dist., 14a,** Bogra, **93f; Burdwan Dist.,** Asansol, **93f,** Burdwan, **93f,** Kalna, **93f,** Memari, **93f; Cooch Behar State, 14a; Dacca Dist.,** Manikganj, **93f; Darjeeling Dist.,** Marianbari, **129d,** Siliguri, **93f; Dinajpur Dist.,** Parbatipur, **MB-3-29; Faridpur Dist., 14a,** Faridpur, **93f; Hooghly Dist.,** Hooghly, **93f; Howrah Dist.,** Belur, **93f; Jalpaiguri Dist.,** Madarihat, **95d,** Saontalpur, **KL-57-28; Jessore Dist., 14a,** Bongaon, **93f,** Jessore, **93f; Khulna Dist., 14a,** Khulna, **93f; Malda Dist., 14a,** Malda, **93f; Midnapur Dist.,** Midnapur, **93f; Murshidabad Dist.,** Berhampore, **93f; Mymensingh Dist.,** Mymensingh, **93f; Nadia Dist.,** Birnagar, **MB-240-30,** Khoksa, **MB-322-30,** Krishnagar, **93f, 95e; Noakhali Dist.,** Noakhali, **93f; Pabna Dist., 14a,** Pabna, **93f; Rajshahi Dist., 14a; Rangpur Dist.,** Rangpur, **93f,** Saidpur, **MB-3-29; Tippera Dist.,** Comilla, **93f; 24-Parganas Dist.,** Kanchrapara, **MB-322-30,** Baranagar, **39g,** Baraset, **39g,** Baruigar, **39g,** Baruipur, **39g,** Behala, **39g,** Dum-Dum, **39g,** Khandah, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BIHAR.

Bhagalpur Dist., Bhagalpur, **114a; Darbhanga Dist.,** Pusa, **MB-25-31; Gaya Dist.,** Gaya, **MB-28,** Tekari, **KL-72-28,** Wazirganj, **KL-72-28; Patna**

Dist., Dinapore, **MB-28; Purnea Dist.,** Katihar, **25a,** Kierpur, **25a,** Purnea, **MB-223-30; Saran Dist.,** Siripur, **25a.**

BOMBAY DECCAN.

Poona Dist., Kirkee, **MB-11-30,** Lonavla, **MB-226-29,** Poona, **MB-28; Sholapur Dist.,** Kurduvadi, **MB-400-30.**

BURMA (LOWER).

Salween Dist., Papun, **MB-26.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c; Hsipaw State** (N. Shan States), Hsipaw, **106e; Minbu Dist.,** Mezali, **106h,** Pwinbyu, **106i; Myitkyina Dist.,** Myitkyina, **120,** Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127b; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL PROVINCES (WEST).

Bhandara Dist., Itkhala, **MB-5-29.**

CHOTA NAGPUR.

Hazaribagh Dist., Chatra, **KL-72-28,** Damodar, **KL-5-29,** Hazaribagh, **114,** Kodarma, **KL-5-29,** Mirzaganj, **KL-72-28,** Ramgarh, **KL-72-28; Ranchi Dist.,** Namkum, **MB-223-30; Singhbhum Dist.,** Dangoaposi, **80i.**

GUJARAT.

Gohelwar (Kathiawar), Bhavnagar, **83g.**

HYDERABAD (NORTH).

Aurangabad Dist., Aurangabad, **142.**

KONKAN.

Kolaba Dist., Karjat, **MB-3-30.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y,** Humma, **130w; Godaveri Dist.,** Yanaon, **116; Vizagapatam Dist.,** Lammasingi, **135.**

MADRAS DECCAN.

Bellary Dist., Kummataravu, **130i; Cuddapah Dist.,** Talamanchipatnam, **130i; Kurnool Dist.,** Kurnool, **130r,** Nandyal, **130t,** Owk Union, **130q.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Coimbatore, **129a; Nilgiris Dist.,** Coonoor, **129a,** Ootacamund, **130aa; North Arcot Dist.,** Tirumalai Hills, **130b; Tanjore Dist.,** Karikal, **116.**

MALABAR.

Coorg Province, Mercara, **54d; Malabar Dist.,** Cannanore, **KL-60-29; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-352-30; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Kohat Dist., Kohat, **MB-202-30; Peshawar Dist.,** Nowshera, **MB-26,** Peshawar, **MB-20-29.**

ORISSA.

Keonjhar State, Uluburo, **KL-71-28; Puri Dist.,** Balighai, **25a,** Barkul, **25a,** Bhubaneswar, **25a.**

PUNJAB (EAST & NORTH).

Gujranwala Dist., Khanki, **83i; Gujrat Dist.,** Kathala, **83i; Karnal Dist.,** Karnal, **MB-292-30.**

PUNJAB (SOUTH-WEST).

Multan Dist., Multan, **MB-28.**

SIND.

Larkana Dist., MB-29.

UNITED PROVINCES (WEST).

Naini Tal Dist., Kichcha, **MB-306-30.**

WAZIRISTAN.

Bannu Area, Mari Indus, **MB-26.**

insulae-florum.

BENGAL.

Darjeeling Dist., Marianbari, **129g,** Sukna, **129g.**

CEYLON (Carter), **129g.**

KONKAN.

N. Kanara Dist., Karwar, **129g,** Yellapur, **129g.**

jamesii.

ASSAM.

Cachar Dist., Labac, **MB-27.**

BENGAL.

Darjeeling Dist., 14a, Marianbari, **129d; *Burdwan Dist.,** Asansol, **93f; *Chittagong Dist.,** Chittagong, **93f; *Dacca Dist.,** Dacca, **93f; *Malda Dist.,** Malda, **93f; *Mymensingh Dist.,** Mymensingh, **93f; *Nadia Dist.,** Krishnagar, **93f; *Noakhali Dist.,** Noakhali, **93f.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26; Poona Dist.,** Lonavla, **MB-2-30.**

BURMA (LOWER).

Salween Dist., Papun, **127a.**

CENTRAL PROVINCES (WEST).

Bhandara Dist., Itkhala, **MB-5-29,** Palasgaon, **MB-5-29.**

CHOTA NAGPUR.

Singhbhum Dist., Manharpur, **80i.**

HYDERABAD (NORTH).

Aurangabad Dist., Aurangabad, **142.**

KONKAN.

Kolaba Dist., Karjat, **MB-21-29.**

MADRAS COAST (NORTH).

Nellore Dist., Duttalur, **47b,** Udayagiri, **47c; Vizagapatam Dist.,** Jeypore, **MB-379-30,** Vizagapatam, **80g, 129a,** Peddavalasa, **135.**

* In the article here cited, the authors state that the 27 larvæ of *jamesii* found in their survey 'must have included some *maculipalpis*, the adults of which were quite common' Apparently no adults of *A. jamesii* were caught or bred out. Under the circumstances these records from Bengal are considered as doubtful.

MADRAS (SOUTH-EAST).

Madura Dist., Rameswaram, **130f; N. Arcot Dist.,** Chittoor, **MB-28,** Tirumalai Hills, **MB-141-30,** Tirupati, **130a; Tanjore Dist.,** Vedaranyam, **MB-28.**

MALABAR.

Coorg Province, Verajpet, **54d; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Bangalore Dist., Bangalore, **144; Chitaldrug Dist.,** Hiriyur, **144; Kadur Dist.,** Mudgere, **144; Mysore Dist.,** Nagenhalli, **144.**

ORISSA.

Keonjhar State, Uluburo, **KL-71-28.**

jeyporiensis.

ASSAM.

Cachar Dist., Labac, **MB-27.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c; Mandalay Dist.,** Maymyo, **MB-261-30; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL INDIA (EAST).

Rewah State, Birsinghpur, **MB-11-29.**

CENTRAL PROVINCES (WEST).

Jubbulpore Dist., Jubbulpore, **MB-250-30.**

CHOTA NAGPUR.

Hazaribagh Dist., Hazaribagh, **114,** Manda, **KL-5-29; Ranchi Dist.,** Namkum, **MB-340-30.**

GUJARAT.

Baroda State, Baroda, **136.**

KONKAN.

Kolaba Dist., Karjat, **MB-21-29, MB-3-30, MB-6-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Chintapalli, **135,** Jeypore, **MB-386-30,** Vizagapatam, **80h, MB-140-30.**

MADRAS DECCAN.

Bellary Dist., Bellary, **130o,** Kummataravu, **130k.**

MADRAS (SOUTH-EAST).

Nilgiris Dist., Ootacamund, **129a.**

MALABAR.

Coorg Province, 122, Mercara, **54d,** Verajpet, **54d; Malabar Dist.,** Malapurram, **MB-27; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30; Mysore Dist.,** Nagenhalli, **144.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Kichcha, **MB-294-30.**

karwari.

ASSAM.

Cachar Dist., Labac, **MB-27,** Sylhet Dist., **93h.**

BENGAL.

Jalpaiguri Dist., Jalpaiguri, **MB-302-30,** Meenglas, **MB-9-29.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26.**

KONKAN.

Kolaba Dist., Karjat, **MB-212-29, MB-3-30, MB-6-30.**

MADRAS DECCAN.

Bellary Dist., Bellary, **130o, 129a.**

MALABAR.

Coorg Province, 122, Mercara, **54d; Malabar Dist.,** Palghat, **130e; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Kadur Dist., Mudgere, **144.**

kochi.

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Goalpara Dist., 14a; Kamrup Dist.,** Gauhati, **MB-80-30; Sibsagar Dist.,** Mariani, **148.**

BENGAL.

Dacca Dist., Dacca, **93f; Darjeeling Dist.,** Marianbari, **129d,** Siliguri, **93f; Jalpaiguri Dist.,** Jalpaiguri, **MB-28,** Sailihat, **MB-1-28.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106e; Myitkyina Dist.,** Myitkyina, **120; N. Hsenwi State** (N. Shan States), Lashio, **106d; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127b.**

leucosphyrus.

ASSAM.

Cachar Dist., Labac, **MB-27; Kamrup Dist.,** Gauhati, **MB-165-29; Sibsagar Dist.,** Mariani, **148.**

BURMA (UPPER).

Upper Chindwin Dist., Mawlaik, **127b.**

MYSORE STATE.

Kadur Dist., Mudgere, **144.**

lindesaii.

MADRAS DECCAN.

Anantapur Dist., MB-26.

N. W. F. P.

Kohat Dist., Kohat, **MB-224-29, MB-5-30; Peshawar Dist.,** Jamrud, **MB-204-29,** Risalpur, **MB-374-30; Swat Territory,** Malakand, **MB-64-30.**

SIKKIM.

Gangtok, **MB-28.**

UNITED PROVINCES (WEST).

Almora Dist., Binsar, **25a; Dehra Dun Dist.,** Chakrata, **MB-168-29.**

WAZIRISTAN.

Bannu Area, Damdil, **MB-26.**

listonii.

ASSAM.

Goalpara Dist., 14a.

BALUCHISTAN.

Loralai Dist., Loralai, **KL-76-28; Zhob Dist.,** Fort Sandeman, **MB-118-29, MB-241-30.**

BENGAL.

Bogra Dist., 14a; Cooch Behar State, 14a; Darjeeling Dist., Marianbari, **129c; Jalpaiguri Dist.,** Madarihat, **95d; Malda Dist., 14a; Nadia Dist.,** Birnagar, **MB-342-30; Rajshahi Dist., 14a; Rangpur Dist., 14a.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26; Poona Dist.,** Jejuri, **MB-225-29,** Lonavla, **MB-2-30,** Paud, **MB-225-29; Satara Dist.,** Lonand, **MB-225-29; Sholapur Dist.,** Kurduvadi, **MB-183-30.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106e; Mandalay Dist.,** Maymyo, **MB-18-30, 138; N. Hsenwi State** (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30.**

CENTRAL INDIA (EAST).

Rewah State, Birsinghpur, **MB-11-29.**

CHOTA NAGPUR.

Hazaribagh Dist., Bagodar, **KL-29,** Champara, **KL-72-28,** Hazaribagh, **114; Ranchi Dist.,** Namkum, **MB-377-30; Singhbhum Dist.,** Dangoaposi, **80i.**

GUJARAT.

Baroda State, Baroda, **136,** Navsari, **MB-315-30,** Vyara, **MB-197-30; Halar** (Kathiawar), Rajkot, **KL-3-29.**

KONKAN.

Kolaba Dist., Karjat, **MB-21-29, MB-3-30; Savantvadi State, MB-10-30.**

MADRAS COAST (NORTH).

Nellore Dist., Mopad, **47a,** Udayagiri, **47c; Vizagapatam Dist.,** Jeypore, **MB-388-30,** Kolab Bridge, **KL-103-28,** Chintapalli, **135,** Lammasingi, **135,** Peddavalasa, **135,** Krishnadevipet, **135,** Vizagapatam, **MB-140-30.**

MADRAS DECCAN.

Bellary Dist., Hirekal, **130n,** Kummataruvu, **130k,** Ramandrug, **129a,** Siriguppa, **130n; Cuddapah Dist.,** Janganapalli, **130i,** Talamanchipatnam, **130i; Kurnool Dist.,** Kurnool, **130r,** Nandyal, **130t.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Mettupalaiyam, **129a; N. Arcot Dist.,** Tirumalai Hills, **MB-141-30; S. Arcot Dist.,** Vriddachalam, **129a.**

MALABAR.

Coorg Province, Mercara, **54d,** Somwarpet, **54d,** Verajpet, **54d; Malabar Dist.,** Anayarkuni, **130d,** Palghat, **130e; Travancore State, 146.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30, 144; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Kohat Dist., Khushalghar, **83a; Peshawar Dist.,** Dargai, **MB-128-29,** Jamrud, **MB-81-30,** Landikotal, **MB-100-29,** Risalpur, **MB-252-30; Swat Territory,** Chakdara, **MB-85-29,** Malakand, **MB-242-30.**

PUNJAB (EAST & NORTH).

Gujranwala Dist., Chakanwali, **124,** Gujranwala, **83i; Gurdaspur Dist.,** Bakloh, **MB-66-29; Jhelum Dist.,** Jhelum, **MB-210-29,** Kallar Kahar (Chakwal Tehsil), **143; Karnal Dist.,** Indri, **MB-25-30; Patiala State,** Pinjaur, **MB-33-31; Rawalpindi Dist.,** Rawalpindi, **MB-39-30.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Banda, **MB-294-30,** Kashipur, **MB-27,** Kichcha, **MB-294-30,** Rudarpur, **118.**

WAZIRISTAN.

Bannu Area, Mir Ali (nr. Idak), **129b.**

ludlowii.

BENGAL.

Backergunge Dist., Barisal, **93f; Chittagong Dist.,** Chittagong, **93f; 24-Parganas Dist.,** Matla, **25a.**

maculatus
maculatus var. **willmori.**

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Goalpara Dist., 14a; Kamrup Dist.,** Gauhati, **MB-165-29; Sibsagar Dist.,** Mariani, **148; Sylhet Dist.,** Adampur, **MB-28.**

BENGAL.

Darjeeling Dist., Marianbari, **129c,** Siliguri, **93f; Jalpaiguri Dist.,** Jalpaiguri, **93f,** Madarihat, **95d; Rangpur Dist.,** Rangpur, **93f.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c; Hsipaw State** (N. Shan States), Hsipaw, **106e; Mandalay Dist.,** Maymyo, **138; Myitkyina Dist.,** Myitkyina, **120,** Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127b; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL INDIA (EAST).

Rewah State, Birsinghpur, **MB-11-29.**

CENTRAL PROVINCES (WEST).

Jubbulpore Dist., Jubbulpore, **MB-250-30.**

CHOTA NAGPUR.

Ranchi Dist., MB-138-27; Singhbhum Dist., Noamundi, **MB-13-29.**

KONKAN.

Kolaba Dist., Karjat, **MB-212-29, MB-3-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Jeypore, **MB-388-30,** Koraput, **130x,** Krishnadevipet, **135,** Lammasingi, **135.**

MADRAS DECCAN.

Bellary Dist., Bellary, **129a,** Kummataruvu, **130k,** Ramandrug, **129a.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Mettupalaiyam, **129a; N. Arcot Dist.,** Tirumalai Hills, **130b.**

MALABAR.

Coorg Province, Mercara, **54d; Malabar Dist.,** Anayarkuni, **130d,** Palghat, **130e; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Kadur Dist., Mudgere, **144.**

N. W. F. P.

Kohat Dist., Hangu, **MB-50-30,** Kohat, **MB-173-30; Peshawar Dist.,** Landikotal, **MB-49-27,** Nowshera, **MB-33-27,** Peshawar, **MB-27, 74a; Swat Territory,** Chakdara, **MB-324-30,** Malakand, **MB-119-29.**

ORISSA.

Keonjhar State, Uluburo, **KL-71-28.**

PUNJAB (EAST & NORTH).

Karnal Dist., Karnal, **MB-64-31; Patiala State,** Pinjaur, **MB-33-31.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Banbassa, **MB-294-30,** Rudarpur, **118; Saharanpur Dist.,** Hardwar, **131.**

WAZIRISTAN.

Bannu Area, Damdil, **MB-26.**

maculipalpis var. **indiensis.**

ASSAM.

Sylhet Dist., Luckerpore Valley, **MB-28.**

BALUCHISTAN.

Zhob Dist., Fort Sandeman, **MB-96-30.**

BENGAL.

Birbhum Dist., Suri, **93f; Burdwan Dist.,** Asansol, **93f; Darjeeling Dist.,** Marianbari, **129c.**

BOMBAY DECCAN.

Poona Dist., Kirkee, **MB-11-30.**

BURMA (LOWER).

Salween Dist., Papun, **127a.**

BURMA (UPPER).

Myitkyina Dist., Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **106d,** Namtu, **MB-327-30; Upper Chindwin Dist.,** Mawlaik, **127b; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL INDIA (WEST).

Gwalior State, Neemuch, **MB-199-29.**

CHOTA NAGPUR.

Hazaribagh Dist., Bagodar, **KL-5-29,** Hazaribagh, **114; Ranchi Dist.,** Namkum, **MB-40-30; Singhbhum Dist.,** Dangoaposi, **80i,** Noamundi, **MB-13-29.**

GUJARAT.

Baroda State, Baroda, **136.**

KONKAN.

Kolaba Dist., Karjat, **MB-6-30, MB-21-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Vizagapatam, **129a.**

MADRAS DECCAN.

Kurnool Dist., Kurnool, **130r.**

MALABAR.

Coorg Province, 122, Mercara, **54d,** Fraserpet, **54d,** Verajpet, **54d; Travancore State,** Vandiperiyar, **MB-27.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **144; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Chitral State, Drosh, **KL-50-29; Kohat Dist.,** Hangu, **MB-72-30; Peshawar Dist.,** Nowshera, **MB-26; Swat Territory,** Chakdara, **MB-84-29,** Malakand, **MB-100-30.**

ORISSA.

Patna State, Titalagarh, **MB-15-29.**

PUNJAB (EAST & NORTH).

Gujranwala Dist., Chakanwali, **124, 132; Gujrat Dist.,** Kathala, **83i; Gurdaspur Dist.,** Bakloh, **MB-31-29; Karnal Dist.,** Karnal, **MB-381-30; Patiala State,** Pinjaur, **MB-63-31; Rawalpindi Dist.,** Rawalpindi, **MB-39-30.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Banbassa, **MB-294-30,** Kichcha, **MB-294-30,** Rudarpur, **118.**

WAZIRISTAN.

Bannu Area, Idak, **MB-124-29,** Mir Ali (nr. Idak), **129a.**

majidi.

BENGAL.

Darjeeling Dist., Marianbari, **129d; Jalpaiguri Dist.,** Bethbari, **39h,** Dalinkote, **39h.**

MALABAR.

Coorg Province, Mercara (Brahman Valley), **39h, 54e, 54f, 122; Malabar Dist.,** Meppadi, **MB-18-29.**

MYSORE STATE.

Kadur Dist., Mudgere, **144.**

minimus.

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Goalpara Dist.,** Kuchugaon, **MB-26; Kamrup Dist.,** Gauhati, **MB-165-29; Sibsagar Dist.,** Mariani, **148; Sylhet Dist., 93h.**

BENGAL.

Bogra Dist., 14a; Cooch Behar State, 14a; Darjeeling Dist., Marianbari, **129c; Dinajpur Dist.,** Parbatipur, **MB-3-29; Malda Dist., 14a; Nadia Dist.,** Birnagar, **95e,** Krishnagar, **95e; Rajshahi Dist., 14a; Rangpur Dist., 14a.**

BIHAR.

Purnea Dist., 14a, Katihar, **MB-3-29.**

BURMA (LOWER).

Salween Dist., Papun, **127a.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106e; Mandalay Dist.,** Maymyo, **138, MB-40-29, MB-261-30; Minbu Dist.,** Mezali, **106h; Myitkyina Dist.,** Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **106d; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127b; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CHOTA NAGPUR.

Ranchi Dist., Namkum, **MB-107-27.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y,** Humma, **130w; Nellore Dist.,** Udayagiri, **130w; Vizagapatam Dist.,** Chintapalli, **135,** Jeypore, **MB-378-30, MB-388-30,** Kolab Bridge, **KL-103-28,** Peddavalasa, **135.**

MADRAS DECCAN.

Bellary Dist., Hospet, **130m,** Kummataravu, **130k; Kurnool Dist.,** Nandyal, **130t.**

MADRAS (SOUTH-EAST).

Madura Dist., Rameswaram, **130f; Tanjore Dist.,** Vedaranniyam, **130c.**

MALABAR.

Coorg Province, Mercara, **54d,** Somwarpet, **54d.**

MYSORE STATE.

Bangalore Dist., Bangalore, **144; Chitaldrug Dist.,** Hiriyur, **144; Kadur Dist.,** Mudgere, **144; Mysore Dist.,** Nagenhalli, **144.**

UNITED PROVINCES (WEST).

Naini Tal Dist., Banbassa, **MB-294-30,** Kichcha, **MB-294-30.**

moghulensis.

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26, MB-188-30; Poona Dist.,** Ahmednagar, **MB-222-29,** Purandhar, **KL-89-28.**

CENTRAL PROVINCES (WEST).

Jubbulpore Dist., Jubbulpore, **MB-250-30.**

CHOTA NAGPUR.

Singhbhum Dist., Noamundi, **MB-36-31.**

DELHI PROVINCE, **MB-27, 80j.**

KONKAN.

Bombay City, MB-28, 145c; Kolaba Dist., Karjat, **MB-3-30, MB-6-30, MB-13-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Vizagapatam, **129a.**

MADRAS DECCAN.

Bellary Dist., Bellary, **129a,** Ramandrug, **129a.**

MADRAS (SOUTH-EAST).

Coimbatore Dist., Mettupalaiyam, **129a.**

MALABAR.

Malabar Dist., Palghat, **130e.**

N. W. F. P.

Kohat Dist., Kohat, **MB-27-27; Peshawar Dist.,** Risalpur, **MB-364-30.**

multicolor.

BALUCHISTAN.

Zhob Dist., Fort Sandeman, **MB-164-28.**

pallidus.

ASSAM.

Kamrup Dist., Gauhati, **MB-80-30; Sibsagar Dist.,** Golaghat, **MB-26.**

BENGAL.

Birbhum Dist., Suri, **93f; Burdwan Dist.,** Asansol, **93f; Cooch Behar State, 14a; Darjeeling Dist.,** Marianbari, **129d; Faridpur Dist.,** Faridpur, **93f,** Rajbari, **MB-8-29; Hooghly Dist.,** Hooghly, **93f; Jessore Dist.,** Bongaon, **93f, MB-325-30; Nadia Dist.,** Birnagar, **MB-246-30, MB-262-30,** Krishnagar, **MB-27, 93f; Pabna Dist., 14a; Rangpur Dist., 14a.**

BIHAR.

Darbhanga Dist., Pusa, **MB-25-31; Gaya Dist.,** Aurangabad, **KL-5-29,** Gaya, **MB-8-30,** Tekari, **KL-72-28; Purnea Dist.,** Katihar, **MB-3-29,** Purnea, **MB-316-30.**

BOMBAY DECCAN.

Dharwar Dist., Hubli, **MB-207-30; Sholapur Dist.,** Kurduvadi, **MB-319-30.**

BURMA (LOWER).

Salween Dist., Papun, **127a, MB-26.**

CENTRAL INDIA (EAST).

Rewah State, Sutna, **MB-187-30.**

CENTRAL INDIA (WEST).

Gwalior State, Neemuch, **MB-199-30.**

CENTRAL PROVINCES (WEST).

Jubbulpore Dist., Jubbulpore, **MB-178-30, MB-250-30; Nagpur Dist.,** Kamptee, **MB-28.**

CEYLON, **13a.**

CHOTA NAGPUR.

Hazaribagh Dist., Champara, **KL-72-28,** Chatra, **KL-72-28,** Damodar, **KL-5-29,** Hazaribagh, **114,** Kodarma, **KL-72-28,** Ramgarh, **KL-72-28.**

GUJARAT.

Baroda State, Navsari, **MB-315-30,** Vyara, **MB-215-30; Sorath** (Kathiawar), Sasan, **83d.**

HYDERABAD (SOUTH).

Atraf-i-Balda Dist., Hyderabad, **MB-23-29.**

KONKAN.

Bombay City, MB-28, 145c; Kolaba Dist., Karjat, **MB-212-29, MB-21-30.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y,** Humma, **130w; Vizagapatam Dist.,** Jeypore, **MB-379-30, MB-386-30,** Krishnadevipet, **135,** Peddavalasa, **135,** Vizagapatam, **129a, MB-366-30.**

MADRAS DECCAN.

Anantapur Dist., MB-26; Bellary Dist., Hospet, **130m,** Kummataravu, **130k; Cuddapah Dist.,** Talamanchipatnam, **130i; Kurnool Dist.,** Koilkuntla, **130s,** Kurnool, **130r,** Nandyal, **130t,** Owk Union, **130q.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30, 144.**

PUNJAB (EAST & NORTH).

Gujranwala Dist., Khanki, **83i.**

UNITED PROVINCES (EAST).

Gorakhpur Dist., Gorakhpur, **MB-28; Lucknow Dist.,** Lucknow, **MB-28.**

UNITED PROVINCES (WEST).

Agra Dist., Agra, **MB-234-30, MB-301-30; Naini Tal Dist.,** Banda, **MB-294-30,** Kichcha, **MB-325-30.**

philippinensis.

ASSAM.

Cachar Dist., Labac, **93e, 147; Goalpara Dist., 14a; Kamrup Dist.,** Gauhati, **KL-54-29; Lakhimpur Dist.,** Panitola, **MB-27; Sibsagar Dist.,** Golaghat, **MB-26,** Mariani, **148.**

BENGAL.

Bogra Dist., 14a; Cooch Behar State, 14a; Darjeeling Dist., 14a; Dinajpur Dist., 14a; Faridpur Dist., 14a; Jessore Dist., 14a; Khulna Dist., 14a; Malda Dist., 14a; Murshidabad Dist., 14a; Nadia Dist., Birnagar, **MB-240-30, MB-246-30,** Khoksa, **MB-322-30,** Krishnagar, **MB-154-27; Pabna Dist., 14a; Rajshahi Dist., 14a; Rangpur Dist., 14a; 24-Parganas Dist., 14a,** Kanchrapara, **MB-322-30.**

BIHAR.

Purnea Dist., Purnea, **MB-338-30, MB-346-30.**

BURMA (LOWER).

Salween Dist., Papun, **MB-26.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106c; Minbu Dist.,** Mezali, **106h,** Pwinbyu, **106i; N. Hsenwi State** (N. Shan States), Lashio, **106d; Myitkyina Dist.,** Myitkyina, **120; Upper Chindwin Dist.,** Mawlaik, **MB-133-27, 127b; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

KONKAN.

N. Kanara Dist., Yellapur, **MB-27.**

MALABAR.

Coorg Province, MB-27, Mercara, **54d,** Somwarpet, **54d.**

MYSORE STATE.

Bangalore Dist., Bangalore, **144; Chitaldrug Dist.,** Hiriyur, **144; Kadur Dist.,** Mudgere, **144; Mysore Dist.,** Nagenhalli, **144.**

pulcherrimus.

BALUCHISTAN.

Zhob Dist., Fort Sandeman, **MB-125-30, MB-152-30.**

N. W. F. P.

Peshawar Dist., Jamrud, **MB-142-29,** Nowshera, **MB-26.**

PUNJAB (EAST & NORTH).

Ferozepore Dist., Ferozepore, **MB-192-29; Gujranwala Dist.,** Chakanwali, **124, 132.**

SIND.

Hyderabad Dist., Badin, **112c,** Dero Mahbat, **112c,** Guni, **112c,** Tando Bago, **MB-344-30; Larkana Dist.,** Larkana, **MB-27,** Khambar, **MB-28,** Walid, **112d; Nawabshah Dist., MB-29; Thar and Parkar Dist., MB-29,** Jamesabad, **112b,** Mirpur Khas, **112b; Sukkur Dist.,** Shikarpur, **112a.**

UNITED PROVINCES (WEST).

Saharanpur Dist., Saharanpur, **MB-27.**

ramsayi.

ASSAM.

Cachar Dist., Labac, **MB-27; Kamrup Dist.,** Gauhati, **KL-126-28.**

BENGAL.

Burdwan Dist., Katwa, **93f,** Memari, **93f; Faridpur Dist.,** Pachooria, **93f; Jalpaiguri Dist.,** Meenglas, **MB-6-28; Jessore Dist., 14a; Khulna Dist., 14a,** Khulna, **93f; Malda Dist.,** Rohanpur, **93f; Mymensingh Dist.,** Bidyagunj, **93f; Nadia Dist.,** Badkulla, **93f,** Birnagar, **MB-240-30, MB-246-30,** Khoksa, **MB-322-30,** Krishnagar, **MB-27; Noakhali Dist.,** Chaumuhani, **93f; 24-Parganas Dist.,** Baranagar, **39g,** Baraset, **39g,** Baruigar, **39g,** Baruipur, **39g,** Behala, **39g,** Dum-Dum, **39g,** Khandah, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **MB-27.**

CEYLON, **13a.**

ORISSA.

Orissa Delta, **MB-186-28.**

sergentii.

WAZIRISTAN.

Derajat Area, Jandola, **129h,** Sarwakai, **129h.**

sintoni.

MALABAR.

Malabar Dist., Calicut, **129f,** Pudapadi, **129f.**

stephensi.

BALUCHISTAN.

Loralai Dist., Loralai, **MB-146-29; Quetta-Pishin Dist.,** Pishin, **MB-43-29; Zhob Dist.,** Murgha, **MB-117-27.**

BENGAL.

Burdwan Dist., Asansol, **93f; Darjeeling Dist.,** Kurseong, **MB-125-27; Nadia Dist.,** Krishnagar, **93f, 95e; 24-Parganas Dist., 14a.**

BIHAR.

Bhagalpur Dist., Bhagalpur, **114a; Patna Dist.,** Dinapore, **MB-27.**

BOMBAY DECCAN.

Poona Dist., Dhond, **MB-394-30,** Jejuri, **MB-225-29; Satara Dist.,** Lonand, **MB-225-29,** Padegaon, **MB-225-29; Sholapur Dist.,** Kurduvadi, **MB-397-30.**

BURMA (UPPER).

Mandalay Dist., Maymyo, **138, KL-106-29; Minbu Dist.,** Mezali, **106h; Upper Chindwin Dist.,** Mawlaik, **127b.**

CHOTA NAGPUR.

Singhbhum Dist., Manharpur, **80i.**

GUJARAT.

Baroda State, Baroda, **136,** Navsari, **MB-266-30,** Vyara, **MB-197-30; Gohelwar** (Kathiawar), Bhavnagar, **MB-287-30; Halar** (Kathiawar), Rajkot, **83h; Jhalawar** (Kathiawar), Wadhwan, **83e; Sorath** (Kathiawar), Junagadh, **83f,** Sasan, **83d.**

HYDERABAD (NORTH).

Aurangabad Dist., Aurangabad, **142.**

KONKAN.

Kolaba Dist., Karjat, **MB-27-30, MB-52-30.**

MADRAS COAST (NORTH).

Nellore Dist., Duttalur, **47b,** Mopad, **47a,** Udayagiri, **47c.**

MADRAS DECCAN.

Anantapur Dist., Anantapur, **MB-26; Kurnool Dist.,** Kurnool, **130r.**

MADRAS (SOUTH-EAST).

N. Arcot Dist., Tirupati, **130a.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **144; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Kohat Dist., Khushalgar, **83a; Peshawar Dist.,** Dargai, **MB-128-29,** Jamrud, **MB-189-29,** Shahgai, **MB-29-29; Swat Territory,** Chakdara, **MB-113-29,** Malakand, **MB-55-29.**

PUNJAB (EAST & NORTH).

Gujranwala Dist., Chakanwali, **124, 132,** Khanki, **83i; Jhelum Dist.,** Kallar Kahar (Chakwal Tehsil), **143; Karnal Dist.,** Karnal, **MB-27-29.**

RAJPUTANA (EAST).

Ajmer-Merwara Province, Ajmer, **MB-283-30; MB-341-30; Udaipur State,** Udaipur, **MB-26.**

SIND.

Hyderabad Dist., Dero Mahbat, **112c,** Guni, **112c,** Tando Bago, **112c; Larkana Dist.,** Larkana, **MB-27,** Walid, **112d; Sukkur Dist.,** Shikarpur, **112a; Upper Sind Frontier Dist.,** Jacobabad, **MB-29.**

UNITED PROVINCES (WEST).

Muttra Dist., Muttra, **MB-26; Saharanpur Dist.,** Roorkee, **MB-113-30.**

WAZIRISTAN.

Bannu Area, Mari Indus, **MB-26,** Mir Ali (nr. Idak), **129b; Derajat Area,** Manzai, **MB-26,** Wana, **MB-53-30, MB-62-30.**

subpictus.

ASSAM.

Kamrup Dist., Gauhati, **MB-74-29.**

BALUCHISTAN.

Loralai Dist., Loralai, **MB-159-29; Quetta-Pishin Dist.,** Chaman, **KL-28; Zhob Dist.,** Fort Sandeman, **MB-70-29.**

BENGAL.

Birbhum Dist., Suri, **93f; Bogra Dist.,** Bogra, **93f; Burdwan Dist.,** Asansol, **93f,** Kalna, **93f,** Memari, **93f,** Nabadwip, **93f; Dacca Dist.,** Manikganj, **93f; Darjeeling Dist.,** Marianbari, **129d,** Siliguri, **93f; Dinajpur Dist.,** Parbatipur, **MB-3-29; Faridpur Dist.,** Faridpur, **93f; Jalpaiguri Dist.,** Madarihat, **95d; Khulna Dist.,** Khulna, **93f; Midnapur Dist.,** Midnapur, **93f; Murshidabad Dist.,** Berhampore, **93f; Mymensingh Dist.,** Mymensingh, **93f; Nadia Dist.,** Birnagar, **MB-246-30,** Krishnagar, **93f, 95e; Pabna Dist.,** Pabna, **93f; Rajshahi Dist., 14a; Rangpur Dist.,** Saidpur, **MB-3-29; Tippera Dist.,** Comilla, **93f; 24-Parganas Dist.,** Baranagar, **39g,** Baraset, **39g,** Baruigar, **39g,** Baruipur, **39g,** Behala, **39g,** Dum-Dum, **39g,** Fraserganj, **25a,** Khandah, **39g,** Matla, **25a,** Sonarpur, **39g,** Tollyganj, **39g.**

BIHAR.

Bhagalpur Dist., Bhagalpur, **114a; Gaya Dist.,** Aurangabad, **KL-5-29,** Barun, **KL-72-28,** Gaya, **MB-8-30,** Shergatti, **KL-72-28,** Tekari, **KL-72-28,** Wazirganj, **KL-72-28; Purnea Dist.,** Purnea, **MB-281-30; Saran Dist.,** Siripur, **25a.**

BOMBAY DECCAN.

Nasik Dist., Igatpuri, **MB-384-30; Poona Dist.,** Lonavla, **MB-226-29,** Sangwi, **MB-225-29; Satara Dist.,** Lonand, **MB-225-29,** Padegaon, **MB-225-29.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c; Hsipaw State** (N. Shan States), Hsipaw, **106e; Minbu Dist.,** Mezali, **106h,** Pwinbyu, **106i; Myitkyina Dist.,** Myitkyina, **120; Upper Chindwin Dist.,** Mawlaik, **127b; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL INDIA (EAST).

Rewah State, Sutna, **MB-187-30.**

CENTRAL INDIA (WEST).

Gwalior State, Bhind, **MB-26,** Neemuch, **MB-199-29.**

tessellatus.

ASSAM.

Cachar Dist., Labac, **MB-27; Sibsagar Dist.,** Mariani, **148; Sylhet Dist.,** Adampur, **MB-58-28.**

BENGAL.

Chittagong Dist., Chittagong, **93f; Dinajpur Dist.,** Parbatipur, **MB-3-29; Jessore Dist., 14a; Khulna Dist., 14a; 24-Parganas Dist.,** Baranagar, **39g,** Behala, **39g,** Dum-Dum, **39g,** Khandah, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26; Poona Dist., MB-26.**

BURMA (UPPER).

Bhamo Dist., Bhamo, **106c, MB-26; Hsipaw State** (N. Shan States), **106e; Mandalay Dist.,** Maymyo, **25a; Yaung Hwe State** (N. Shan States), Shwenyaung, **128.**

CENTRAL PROVINCES (WEST).

Bhandara Dist., Palasgaon, **MB-5-29; Jubbulpore Dist.,** Jubbulpore, **MB-122-29, MB-250-30.**

CHOTA NAGPUR.

Singhbhum Dist., Dangoaposi, **80i,** Manharpur, **80i.**

DELHI PROVINCE, **KL-92-29.**

GUJARAT.

Baroda State, Vyara, **MB-197-30.**

KONKAN.

Kolaba Dist., Karjat, **MB-337-30; Savantvadi State, MB-10-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Jeypore, **MB-388-30,** Krishnadevipet, **135,** Vizagapatam, **MB-366-30.**

MADRAS DECCAN.

Anantapur Dist., Anantapur, **KL-96-29; Cuddapah Dist.,** Talamanchipatnam, **130i.**

MADRAS (SOUTH-EAST).

S. Arcot Dist., Pondicherry, **116.**

MALABAR.

Coorg Province, 122, Somwarpet, **54d; Travancore State,** Vandiperiyar, **MB-37-31.**

MYSORE STATE.

Chitaldrug Dist., Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30, 144; Mysore Dist.,** Nagenhalli, **144.**

theobaldi.

ASSAM.

Cachar Dist., Labac, **MB-13-28.**

CENTRAL INDIA (WEST).

Gwalior State, Neemuch, **MB-199-29; Rewah State,** Birsinghpur, **MB-11-29.**

CHOTA NAGPUR.

Hazaribagh Dist., Hazaribagh, **114; Singhbhum Dist.,** Dangoaposi, **80i.**

GUJARAT.

Baroda State, Baroda, **136,** Vyara, **MB-197-30.**

HYDERABAD (NORTH).

Aurangabad Dist., Aurangabad, **142.**

KONKAN.

Kolaba Dist., Karjat, **MB-21-29, MB-3-30.**

MADRAS COAST (NORTH).

Vizagapatam Dist., Lammasingi, **135,** Vizagapatam, **80g, 129a, MB-12-30, MB-140-30.**

MADRAS DECCAN.

Bellary Dist., Kummataravu, **130k.**

turkhudi.

BALUCHISTAN.

Zhob Dist., Fort Sandeman, **MB-47-29, MB-125-30, MB-241-30.**

BOMBAY DECCAN.

Poona Dist., Lonavla, **MB-4-30,** Poona, **MB-29.**

GUJARAT.

Halar (Kathiawar), Rajkot, **83h; Jhalawar** (Kathiawar), Wadhwan, **83e; Sorath** (Kathiawar), Sasan, **83d.**

KONKAN.

Kolaba Dist., Karjat, **MB-52-30.**

MADRAS DECCAN.

Bellary Dist., Kenchanaguddam, **130n,** Siriguppa, **130n; Kurnool Dist.,** Kurnool, **130r.**

MYSORE STATE.

Bangalore Dist., Bangalore, **144; Chitaldrug Dist.,** Hiriyur, **144; Mysore Dist.,** Nagenhalli, **144.**

N. W. F. P.

Chitral State, Drosh, **MB-50-29; Peshawar Dist.,** Dargai, **MB-128-29,** Landikotal, **MB-120-29, MB-233-30,** Nowshera, **MB-141-29,** Peshawar, **MB-26-29,** Risalpur, **MB-303-30; Swat Territory,** Chakdara, **MB-113-29, MB-371-30,** Malakand, **MB-55-29, MB-64-30.**

PUNJAB (EAST & NORTH).

Patiala State, Pinjaur, **MB-63-31.**

WAZIRISTAN.

Bannu Area, Damdil, **MB-98-28,** Idak, **MB-44-29,** Mir Ali (nr. Idak), **129b.**

umbrosus.

ANDAMANS, **MB-26, 145a.**

vagus.

ASSAM.

Cachar Dist., Labac, **MB-27; Darrang Dist., 93h; Goalpara Dist.,** Kuchugaon, **MB-26; Kamrup Dist.,** Gauhati, **MB-165-29; Sibsagar Dist.,** Mariani, **148.**

BENGAL.

Backergunge Dist., Barisal, **93f; Bankura Dist.,** Bankura, **93f; Birbhum Dist.,** Bolpur, **93f; Bogra Dist., 14a,** Bogra, **93f; Burdwan Dist.,** Asansol,

93f, Burdwan, **93f,** Kalna, **93f,** Memari, **93f; Calcutta, 93f; Chittagong Dist.,** Chittagong, **93f; Cooch Behar State, 14a; Dacca Dist.,** Dacca, **93f, MB-24-30,** Manikganj, **93f; Darjeeling Dist.,** Marianbari, **129d,** Şiliguri, **93f; Dinajpur Dist.,** Dinajpur, **93f;** Parbatipur, **MB-3-29; Faridpur Dist., 14a,** Faridpur, **93f; Hooghly Dist.,** Hooghly, **93f; Jalpaiguri Dist.,** Jalpaiguri, **93f,** Saontalpur, **KL-28; Jessore Dist., 14a,** Bongaon, **93f,** Jessore, **93f; Malda Dist., 14a,** Malda, **93f; Midnapur Dist.,** Midnapur, **93f; Murshidabad Dist.,** Bazar Sohu, **93f,** Berhampore, **93f; Mymensingh Dist.,** Mymensingh, **93f; Nadia Dist.,** Birnagar, **MB-240-30,** Krishnagar, **93f, 95e; Noakhali Dist.,** Noakhali, **93f; Pabna Dist., 14a,** Pabna, **93f; Rajshahi Dist., 14a; Rangpur Dist.,** Rangpur, **93f; Tippera Dist.,** Comilla, **93f; 24-Parganas Dist.,** Sonarpur, **39g.**

BOMBAY DECCAN.

Nasik Dist., Deolali, **MB-26; Poona Dist.,** Lonavla, **MB-226-29,** Paud, **MB-225-29; Satara Dist.,** Lonand, **MB-225-29,** Padegaon, **MB-225-29.**

BURMA (LOWER).

Insein Dist., Mingaladon, **MB-147-30;** Kyaukpyu, **MB-26.**

BURMA (UPPER).

Hsipaw State (N. Shan States), Hsipaw, **106i; Mandalay Dist.,** Maymyo, **25a; Minbu Dist.,** Pwinbyu, **106i; Myitkyina Dist.,** Myitkyina, **120,** Sahmaw, **106f; N. Hsenwi State** (N. Shan States), Lashio, **MB-26; Thayetmyo Dist., 25a; Yaung Hwe State** (S. Shan States), Shwenyaung, **128.**

CENTRAL PROVINCES (WEST).

Jubbulpore Dist., Jubbulpore, **MB-22-30.**

CHOTA NAGPUR.

Hazaribagh Dist., Hazaribagh, **114; Ranchi Dist., MB-138-27; Singhbhum Dist.,** Dangoaposi, **80i.**

KONKAN.

Kolaba Dist., Karjat, **MB-212-29.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y; Godaveri Dist.,** Yanaon, **116; Vizagapatam Dist.,** Jeypore, **MB-379-30, MB-386-30,** Koraput, **130x,** Vizagapatam, **MB-7-30, MB-12-30.**

MADRAS (SOUTH-EAST).

S. Arcot Dist., Pondicherry, **116; Tanjore Dist.,** Karikal, **116.**

MALABAR.

Coorg Province, Fraserpet, **54d,** Verajpet, **54d; Malabar Dist.,** Malappuram, **MB-169-27; Travancore State,** Vandiperiyar, **MB-31-30.**

MYSORE STATE.

Bangalore Dist., Bangalore, **144; Chitaldrug Dist.,** Hiriyur, **144; Kadur Dist.,** Mudgere, **MB-351-30; Mysore Dist.,** Nagenhalli, **144.**

ORISSA.

Patna State, Titalagarh, **133.**

varuna.

BENGAL.

Darjeeling Dist., Marianbari, **129d; Jalpaiguri Dist.,** Rajabhatkawa, **MB-21-29; Jessore Dist., 14a; Khulna Dist., 14a; Murshidabad Dist., 14a; Nadia Dist., 14a; Pabna Dist., 14a; 24-Parganas Dist.,** Baranagar, **39g,** Baraset, **39g,** Baruigar, **39g,** Baruipur, **39g,** Behala, **39g,** Dum-Dum, **39g,** Khandah, **39g,** Sonarpur, **39g,** Tollyganj, **39g.**

BURMA (UPPER).

Myitkyina Dist., Sahmaw, **106f.**

GUJARAT.

Baroda Dist., Vyara, **MB-197-30.**

MADRAS COAST (NORTH).

Ganjam Dist., Berhampore, **130y; Vizagapatam Dist.,** Vizagapatam, **MB-12-30.**

MADRAS (SOUTH-EAST).

S. Arcot Dist., Vriddachalam, **MB-27, 129a, 130h.**

MALABAR.

Travancore State, Vandiperiyar, **MB-27.**

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Records of the Malaria Survey of India, Vol. II, No. 2, June, 1931.

ON A COLLECTION OF ANOPHELINE AND CULICINE MOSQUITOES FROM SIAM.

BY

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DURING a visit made to Siam by Lieut.-Colonel J. A. Sinton, V.C., O.B.E., I.M.S., in connection with the VIIIth Congress of the Far Eastern Association of Tropical Medicine, a collection of Culicidæ was made, as it was thought that mosquitoes from this area would be of interest for comparison with the species found in India.

Apart from one or two records by Theobald, a note regarding species taken in Bangkok by Stanton (1920), a few records of Culicini by Edwards (1922), and two short papers on the Anopheline mosquitoes of Siam by Barnes (1923) there appear to be very few references in the literature to Culicidæ from Siam.

Colonel Sinton's tour was not primarily made with the object of collecting Culicidæ, but every available opportunity was taken to secure as many of these insects as possible, and during his stay of two weeks in Siam, he was able to collect about 1,000 adult and 180 larval specimens from different areas.

In the lower part of Siam during the railway journey through large areas of rice cultivation, interspersed with jungle and low hills, he was able to obtain some adults which had come into the railway carriages and some larvæ from borrow-pits near railway stations. In the deltaic portion of Siam, at Bangkok, a very large collection of adults was made in bed and bath rooms in an hotel. As was to be expected from the very numerous canals and other collections of water due to the high subsoil water level these insects were present in myriads, indeed they formed such a plague that practically every person, no matter how poor, provides himself with a mosquito net as a necessity of life.

Passing north by rail from Bangkok, through the deltaic area, large numbers of mosquitoes were found in railway carriages in the vicinity of electric lights. When the more hilly country in the neighbourhood of Utaradit was reached the

insects were not so numerous. A stay of a few days was made at Chiengmai in Northern Siam. This town lies in a wide fertile valley, at an altitude of about 1,000 ft., between two ranges of hills rising to about 5,000 ft. There is much rice cultivation here watered by streams coming down from the hills. Collections of larvæ were made from some of the fields, irrigation channels, and foothill streams. In some cases adults were bred from these.

As far as could be gathered the deltaic area, which resembles parts of Lower Bengal, had, like these places, a low malarial incidence, but when the hills were reached, and especially round Chiengmai, severe hyperendemic malaria, and blackwater fever, were present.

Whilst dealing with Col. Sinton's collection from Siam it has been thought desirable to summarize at the same time information that has been recorded up to date for this country.

We are much indebted to Dr. I. M. Puri for very kindly making a critical examination of the Anopheline larvæ here dealt with.

ANOPHELINI.

Eighteen species are recorded by Barnes as follows:—

A. funestus (*listonii*).
A. rossii.
A. aconitus.
A. ludlowii.
A. culicifacies.
A. punctulatus (=*tessellatus*).
A. leucosphyrus.
A. minimus.
A. barbirostris.
A. sinensis (*hyrcanus*).
A. maculatus.
A. maculatus var. *willmori.*
A. karwari.
A. maculipalpis.
A. jamesii.
A. fuliginosus.
A. kochi.
A. formosus (?).

Stanton (1920) records in addition *A. sinensis* var *peditaeniatus* (see, however, remarks under *A. hyrcanus* var. *nigerrimus* in this paper), *A. fuliginosus* var. *nivipes* (*A. philippinensis*) and *A. rossii* var. *indefinitus* (*vagus*).

Among the species brought back by Col. Sinton are included two further species *A. pallidus* and *A. ramsayi.*

Regarding Barnes's records: those for *A. rossii* as shown by the material now examined must certainly apply in part to *A. vagus* and in part to *A. rossii* var. *malayensis;* the record of *A. jamesii* almost certainly relates to *A. ramsayi*, the *A. jamesii* of James and Liston to which Barnes refers being this species; the record of var. *willmori* in view of recent work by one of us (S. R. C.) and the examination of material brought back by Col. Sinton is probably best taken as relating to heavily scaled individuals of *A. maculatus* (type); the form of *A. hyrcanus* present as shown later appears to be var. *nigerrimus.* The list of species recorded from Siam up to date may therefore be given as follows:—

A. (*Anopheles*) *formosus* (?).
A. (*Anopheles*) *hyrcanus* var. *nigerrimus.*

A. (*Anopheles*) *barbirostris*.
A. (*Myzomyia*) *tessellatus*.
A. (*Myzomyia*) *leucosphyrus*
A. (*Myzomyia*) *kochi*.
A. (*Myzomyia*) *culicifacies*.
A. (*Myzomyia*) *listonii*.
A. (*Myzomyia*) *minimus*.
A. (*Myzomyia*) *aconitus*.
A. (*Myzomyia*) *vagus*.
A. (*Myzomyia*) *subpictus* var. *malayensis*.
A. (*Myzomyia*) *ludlowii*.
A. (*Myzomyia*) *fuliginosus*.
A. (*Myzomyia*) *philippinensis*.
A. (*Myzomyia*) *pallidus*.
A. (*Myzomyia*) *maculatus*.
A. (*Myzomyia*) *karwari*.
A. (*Myzomyia*) *ramsayi*.
A. (*Myzomyia*) *maculipalpis* var. *indiensis*.

The following is a summary, under the names of the different species of information recorded including the result of examination of Col. Sinton's collection.

A. gigas var. **formosus** Ludlow, 1909.

Given by Barnes as doubtful, the specimens being badly rubbed and identification uncertain. No locality is given.

A. hyrcanus var. **nigerrimus** Giles, 1900.

Syn. *My. argyropus* Swellengrebel, 1914.

Theobald (1910, p. 51) (as *A. sinensis*). Prapatom(1), August, September (Dr. P. G Woolley).

Stanton (1920) (as *A. sinensis* and var. *peditaeniatus* Leic.), Bangkok, Oct.-Nov. 1915; caught as adults in houses and as larvæ in natural collections of water.

Barnes (1923)* (as *A. sinensis*). Bangkok, [28. 11. 14 (C. Boden Kloss),†] Oct. 1921; Prapatom, 1906, 1907 (Dr. P. G. Woolley, *vide* Theo. V.); Koh Chang(2), [6. 12. 24 (C. Boden Kloss)†]. Three hundred specimens taken.

* Practically the same information is given in the two papers by Barnes, but where additional information is given in the paper in *Jour. Nat. Hist. Soc. Siam*, such information is recorded in square brackets.

† References so marked are given by Barnes [*Jour. Nat. Hist. Soc. Siam*] as included in an unpublished paper 'On a small collection of mosquitoes from Siam' by A. T. Stanton and F. W. Edwards, which is stated to be in the files of the Natural History Society of Siam.

(1) Near Bangkok. (2) An island off the coast.

One of the commonest Anophelines found in the houses in the evening in Bangkok; larvæ in grassy portions of flooded fallow land, in grassy ditches and ponds. Exhibits a great deal of variation in the extent of banding of the legs and in wing markings. Specimens conforming to the types of *A. peditaeniatus* Leic. and *A. separatus* Leic. have been found.

Sinton (coll. 1930), 100 ♀♀, 7 ♂♂ caught at evening in bedroom and bathroom in hotel, Bangkok, 3—20. 12. 30; 1 ♀ caught in train near Tungson junction (3) 2. 12. 30; 2 ♀♀, 1 ♂ caught in train near Bandon (3) 2. 12. 30; 1 ♀ caught in train near Chumphon Railway Station (3), 4. 12. 30; 19 larvæ taken in old ricefield, Chiengmai, 16. 12. 30; 15 larvæ from weedy canals and ponds near hotel, Bangkok, 10. 12. 30; 1 larva from moat near Prince's School, Chiengmai, 17. 12. 30.

The series from Bangkok shows all gradations between narrowly banded hind tarsus (8 specimens), somewhat broader to broad pale bands (82 specimens) and very broad bands approaching complete whitening of the last segments of the hind tarsus (13 specimens). The female palpi have the apical and penultimate band about the same width as the intervening dark band, with in some cases some more diffuse white scaling. The front tarsi show apical bands on segments 1–3 with a trace of banding often on 4, the degree of banding being very variable ranging on segment 2 from 1/10 to 1/2 the segment; a broadly banded fore tarsus is present in some specimens with narrow hind tarsal bands. The hind tarsus most frequently with a narrow apical band on segment 1, a broader apical band on segment 2 (from about 1/10 to 1/5 length of the segment), a similar band on segment 3 (about 1/7 to 1/3) and apical and basal bands on 4, segment 5 being in many cases dark. Variation chiefly occurs in the amount of white on segments 4 and 5 there being basal banding on the latter and the dark band on the former showing all degrees of restriction up to complete disappearance. In several specimens the whole tarsus is completely white from the white tipped segment 3 onwards except for the apical half or so of segment 5 which usually remains dark. In other cases segment 5 is almost or entirely white.

The wing has a small, usually more or less fleck-like pale interruption at the subcostal junction on the costa, commonly not continued or only imperfectly continued on to vein 1; a fringe spot is infrequent but sometimes present; there is most commonly nearly continuous dark scaling on vein 1 and on stems of 2 and 4; vein 3 and vein 5 are extensively pale; 2.1 is mainly dark with a dark area on 2.2 at the base which varies from about 1/7 to 1/3 of the branch in length; the dark spots on vein 6 are of very variable extent and the border scales along the base of the fringe may be dark or pale or in part pale and in part dark. In a certain number of specimens the white scaling towards the front of the wing is more accentuated and scattered white scales are present along the middle portion of vein 1 and at its base, more rarely some scattered

(3) South Siam (peninsula).

white scales are present towards the base of the costa, such wings appearing pale with rather discrete black spots. The greatest degree of tarsal whitening is generally associated with a dark wing.

These characters including the variations noted appear identical with those of *A. hyrcanus* from Assam. Most specimens from Calcutta (type locality for var. *nigerrimus*) show a less degree of banding of the tarsus, but quite broad tarsal banding is seen even in specimens from the Punjab. As there appears to be no definable character which can be used to distinguish the present series from var. *nigerrimus* they have been so identified. This is tantamount to the sinking of var. *argyropus* Swell. which is clearly only an advanced degree of tarsal whitening as described in the series. Stanton was evidently influenced by the very broad banding and possibly by wing variation in returning var. *peditaeniatus* as present at Bangkok. In the absence of the larval characters described by Leicester (1908) and more recently recorded by Walch (1930) for a single specimen from Java it does not seem possible to say that the broad banded tarsal form in any particular case is this variety. Larvæ of broad banded forms from Assam recently examined by Barraud have not shown the characters described for the larva of *peditaeniatus*. Larvæ brought from Siam by Col. Sinton were indistinguishable from those of var. *nigerrimus*.*

Three female specimens from Bangkok showed mites attached to the abdomen.

A. barbirostris Van der Wulp, 1884.

Theobald (1910, p. 50). Prapatom, 24. 3. 07 (Dr. P. G. Woolley).

Stanton (1920). Bangkok, Oct.-Nov. 1915; adults caught in houses.

Barnes (1923). Bangkok [26. 11. 14 (C. Boden Kloss)†], Dec. 1916; Prapatom, 1906, 1907 (Dr. P. G. Woolley, *vide* Theo. V.); Meklong(4), Nov. 1921; Rajburi(4), Nov. 1921 (Dr. J. R. Redfield); Prachinburi(5), July 1922 (Lieut. Sawat Manmhai); Trang(3), July 1922 (Lieut. Tong Kham Raggabhai); Lampang(6), June 1920; Chiengmai(6), Feb. 1917. A very commonly found mosquito, seen more frequently about sheds than in dwellings; larvæ found in borders of ricefields, in moats, ponds, etc.

Sinton (coll. 1930). One ♀, 2 ♂♂ caught in bedroom and bathroom in hotel, Bangkok, 11. 12. 30 and 20. 12. 30; 1 ♀ caught in railway carriage near Tungson junction on 2. 12. 30; 5 larvæ from borrow-pits near Rajburi Railway Station, 12. 12. 30; 10 larvæ from gardens of hotel, Bangkok, 6. 12. 30; 3 larvæ from roadside drain, east of Chiengmai, 17. 12. 30; 2 ♂♂ from Bangkok with mites attached to abdomen.

A. tessellatus Theobald, 1901.

Stanton (1920). Bangkok, Oct.-Nov. 1915; adults caught in houses.

Barnes (1923). Bangkok, Oct. 1921; Chiengmai, 31. 3. 20. Though its numbers are small, this species is not rare.

*** These were very kindly examined and reported upon by Dr. Puri.**

(4) Near Bangkok. (5) To east of Bangkok. (6) North Siam.

A. leucosphyrus Donitz, 1901.

Barnes (1923). Hoi Chan Kean Sanatarium, near Chiengmai, 9. 5. 18; Chiengmai, 5. 11. 13. Four specimens.

A. kochi Donitz, 1901.

Barnes (1923). Chiengmai, 13. 8. 20. Twenty specimens taken.

A. culicifacies Giles, 1901.

Barnes (1923). Chiengmai, 22. 8. 20. Rather rarely seen; 5 specimens taken resting on walls in bungalow with culicine attitude.

This appears to be the most easterly record for this species, which is abundant in some parts of Burma but does not seem to have been recorded from Indochina, the Malay Archipelago or F. M. S.

A. listonii Liston, 1901.

Barnes (1923) Bangkok, 25. 10. 21; Chiengmai, 9. 4. 20, 25 8. 20, 3 9. 20. Twenty specimens.

A. minimus Theobald, 1901.

Barnes (1923) Bangkok, 1921. One specimen.

A. aconitus Donitz, 1902.

Barnes (1923). Bangkok, Oct., Nov., Dec. 1921; Chiengmai, 24. 8. 20. Fifteen specimens.

Sinton (coll. 1930). Fifty-eight ♀♀, 9 ♂♂ caught at evening in bedroom and bathroom in hotel, Bangkok, 3—19. 12. 30; 1 larva taken in old ricefield, Chiengmai, 16. 12. 30; 1 larva from borrow-pits near Rajburi Ry. Sta., 21. 12. 30; 13 larvæ from roadside drain, east of Chiengmai, 17. 12. 30. These form a very consistent series, the proboscis in the female in all cases pale in the outer 1/3 to 1/2, with two broad pale bands at the apex of the palps, these about equal in extent and never less than about 3 times, usually about 4 times, the width of the intervening dark area. In some cases the dark band is even narrower and in 30 per cent of the specimens altogether absent, the whole terminal portion of the palpi being uniformly pale. The costa in the basal portion is uniformly dark to the base continuous with the inner dark costal spot except in two specimens where there is a small interruption about half-way between the inner end of the inner dark spot and the base, and in one of these two specimens an additional small interruption at the inner margin of the inner dark spot. Vein 3 is entirely pale at the base except in 3 specimens where there are some dark scales or a short black spot in this situation, one of these having a small spot on each side of the cross-vein. Vein 6 shows three dark spots, the outer and middle one of variable lengths, except in one specimen where the outer half of this vein was continuously dark, though associated with

a fringe spot at its termination. A fringe spot at vein 6 was in most cases present, but sometimes poorly displayed or difficult to verify; in a few cases it was definitely absent, but without any other reason to suppose that the specimen was not the same species as the others. The middle main costal spot was in all cases much shorter internally on vein 1 than on the costa, the pale encroachment in this situation varying from 1/3 (18 specimens) to somewhat less than half (13 specimens) or 1/2 (23 specimens), even in a few cases 2/3 (2 specimens). In somewhat less than half the specimens the stem of vein 2 internal to the dark area just basal to the bifurcation was entirely pale; in the others there were either some dark scales or a dark spot under the middle costal spot. Vein 4.1 in a large proportion of specimens was continuously dark except at the ends, but in others a more or less extensive pale spot was present about its middle. In all these was a pale spot on the fringe associated with pale border scales about half-way between the termination of vein 6 and the base of the wing. All the specimens showed definite paling at the ends of tarsal segments 1–4 on all legs giving a very narrow but none the less very definite banding.

The male palpi showed a well developed pale patch at the apex of segment 3 at the base of the club and the club mainly pale with narrow dark bands at the base and about the middle of this portion, the ventral border being continuously dark.

A. rossii Giles, 1899.

Theobald (1910, p. 19). Prapatom, Jan., Mar., Aug., Sept. 1906, 1907 (Dr. P. G. Woolley).

Barnes (1923). Bangkok, Dec. 1916; Prapatom, 1906, 1907 (Theo. V.); Meklong, Nov. 1921; Rajburi, Oct. 1921 (Dr. Redfield); Prachinburi, July 1922 (Lieut. Sawat Manmhai); Trang, July 1922 (Lieut. Tong Kham Raggabhai); Lampang, June 1920; Chiengmai, 18. 3. 17. The commonest mosquito in Siam.

It is impossible to say with certainty that all these records relate to *A. vagus,* on the other hand it is impossible to say to what extent at the different localities this species or *A. subpictus* var. *malayensis* has been taken.

A. vagus Donitz, 1902.

Stanton (1920) (as *A. rossii* var. *indefinitus*). Bangkok, Oct., Nov. 1915; caught as adults in houses or as larvæ in artificial or natural collections of water.

Sinton (coll. 1930). Fourteen ♀♀, 1 ♂ caught in evening in bedroom and bathroom in hotel, Bangkok, 7—11. 12. 30; 1 ♂ caught Pantalung Ry. Sta., 2. 12. 30; 1 ♂ caught Rajburi Ry. Sta., 3. 12. 30; 1 ♂ caught Lampang Ry. Sta., in train near light, 15. 12. 30; 6 ♀♀, 4 ♂♂ bred from larvæ from ricefields with running water, Chiengmai, 16. 12. 30; 33 larvæ from old ricefield, Chiengmai, 16. 12. 30; 1 larva from borrow-pit near Rajburi Ry Sta., 21. 12. 30; 1 larva from weedy canals and ponds near hotel, Bangkok, 10. 12. 30.

The above females are all typical forms with the pale apical band about three times the dark intervening band, i.e., according to the method of measurement employed by Barber (1918) (first black band/first black band plus terminal white) a ratio of 0 25. About half the specimens show more or less clearly the small pale tache at the sides towards the apex of the proboscis, in some cases almost amounting to a band in appearance, but the proboscis is always actually dark ventrally. The males all show varying conditions of the fiont tarsus described by Rodenwaldt (1922) as characteristic of a *A. vagus* as against *A. subpictus,* but it is not certain that this is always reliable or includes also the form var. *malayensis*. In the case of these males the joint at 4-5 was dark in two specimens, with a narrow apical band on segment 4 in 2 specimens and with a narrow basal band on segment 5 in 2 specimens.

A. subpictus var. **malayensis** Hacker.

Ten ♀ ♀ caught with the last mentioned species at evening in bedroom and bathroom in hotel, Bangkok, 7—11. 12. 30. Three larvæ from weedy canals and ponds near hotel, Bangkok, 10. 12. 30. The females show the pale apical band 1½ to 2 the dark intervening band, or an index according to Barber's method of measurement from 0 4 to 0 3.

A. ludlowii Theobald, 1901.

Barnes (1923). Bangkok, July 1921; Koh Phra(7), 16. 11. 21; Koh Mak(7), 19. 12. 24; Koh Kut(7), [30. 12. 14 (C. Boden Kloss)†]. Over 100 specimens caught in sleeping quarters of guards on quarantine island at Koh Phra, the larvæ found in small salt-water swamp. This species was the only Anopheline found on the island, which is over a mile from the mainland. Malaria was quite prevalent among the guards. Dissection of 25 specimens showed one with oöcysts.

A. fuliginosus Giles, 1900.

Stanton (1920). Bangkok, Oct.-Nov. 1915; adults caught in houses.

Barnes (1923). Bangkok, 1. 10. 21; Chiengmai, 8. 3. 17; Prachinburi, July 1922 (Lieut. Sawah Manmhai). One of the most frequently and commonly found Anopheles in houses on outskirts of Bangkok; adults frequently taken in houses in Chiengmai, larvæ in moats and grassy pools, especially in flooded fallow land.

Sinton (coll. 1930). Fifty-seven ♀ ♀, 3 ♂ ♂ caught at evening in bedroom and bathroom in hotel, Bangkok, 3—19. 12. 30; 1 ♂ in train near Bandon 21. 12. 30 Six larvæ from gardens of hotel, Bangkok, 6. 12. 30; 8 larvæ from weedy canals and ponds near hotel, Bangkok, 10. 12. 30. A very consistent series the female showing complete or incomplete bridging of the subcostal pale area on vein 1, dark middle portion of vein 5, oval spot near apex on mid-femur, 1/6–1/10 of tarsal segment 2 of the hind leg pale, with a distinct apical pale band on

(7) Islands near coast.

segment 1, and other characters typical of *A. fuliginosus.* The most common condition of vein 5 is with a pale spot about the middle of the stem and one towards the base of 5·2 separating off a middle dark area, but one or both of the pale spots may be lacking or nearly so and the whole length of the fifth vein in some specimens therefore almost continuously dark.

A. philippinensis Ludlow, 1902.

Stanton (1920). Bangkok, Oct.-Nov. 1915; adults caught in houses.

Sinton (coll. 1930). One ♀ caught at evening in bedroom or bathroom in hotel, Bangkok, 3. 12. 31; 1 ♀ caught near Utaradit Ry. Sta.,(8) in train near light, 18. 12. 30; 9 larvæ from moat near Prince's School, Chiengmai, 17. 12. 30.

The first specimen with the pale band on segment 2 of the hind tarsus nearly equal to half length of segment; the second with this band about 1/4 the length of the segment, the subcostal spot partially bridged, vein 5 extensively pale.

A. pallidus Theobald, 1901.

Sinton (coll. 1930). Six larvæ from hoof-marks near borrow-pits, Lampang Ry. Sta., 18. 12. 30; 2 larvæ from roadside drain, east of Chiengmai, 17. 12. 30; 6 larvæ from moat near Princes' School, Chiengmai, 17. 12. 30.

A. maculatus Theobald 1901.

Barnes (1923) (as *A. maculatus* and as var. *willmori*). Hoi Chan Kean Sanatarium, near Chiengmai, 8. 5. 18, altitude 2,500 ft. Caught as adults in dormitories at Royal Pages College at foot of Doi Chomchang mountain near Chiengmai, and also bred from larvæ from nearby mountain stream. Larvæ were found in clear water where the current was slow, also in small pools scouped in the sand without visible vegetation. The College was situated on land recently cleared from virgin forest; adults were found in the dormitories along with *A. rossii,* the only other Anopheline present. An epidemic occurred among the teachers and students. (The College has since been abandoned.)

Sinton (coll. 1930). One ♀ bred from larvæ from fallow ricefield with running water, Chiengmai, 16. 12. 30; 7 ♀ ♀ , 6 ♂ ♂ bred from larvæ from foothill stream, Chiengmai, 17. 12. 30; 4 larvæ from hill stream, Chiengmai, 16. 12. 30.

Of the 7 females: 3 showed broadish scaling on segments 2–8 with some degree of a patch of scales on segment 2, none of the specimens showing maculation of the palpi; the remaining 4 showed varying degrees of scaling on the abdomen commonly seen in *A. maculatus* (type). Of the 6 ♂ ♂ three showed scaling on segments 2–8 with some approach to a patch of scales on segment 2, one a moderate degree of scaling and two few or no scales anteriorly. The

(8) South Siam.

ventral and lateral black scaling on the terminal segments of the abdomen was considerably developed in some specimens, less so in others. Two of the *willmori*-like females showed some dark scales on vein 4 between the cross-veins. In several of the specimens the pale line under the mid and hind femur is very marked, extending almost to the full length of the femur.

Though the abdominal scaling in some individuals is indistinguishable from that in var. *willmori,* the variation in the scaling in the series as a whole and the absence of any proof of extensive maculation of the palpi in the females leads us to return these as merely variable degrees of scaling in *A. maculatus* (type) (*vide* Christophers, 1931).

A. karwari James, 1903.

Barnes (1923). Hoi Chan Kean Sanatarium, near Chiengmai, 8. 5. 18, altitude 2,500 ft.

A. ramsayi Covell, 1927.

Barnes (1923) (as *A. jamesii*). Chiengmai, 27. 8. 20; Nong Seng village, Chiengmai, Aug.-Nov. 1920; also bred from larvæ in large grass swamp near Nong Seng village.

Sinton (coll. 1930). One ♀, 1 ♂ caught near Utaradit Ry. Sta., in train near light, 18. 12. 30. The specimens are quite typical.

A. maculipalpis var. **indiensis** Theobald, 1903.

Barnes (1923). Hoi Chan Kean Sanatarium, near Chiengmai, 12. 5. 17, altitude 2,500 ft. Captured attacking ankles under table in evening, very shy of appearing in the light.

CULICINI.

List of Culicini known from Siam.

Megarhinus splendens (Wied.).

,, *magnificus* Leic.

Uranotaenia atra Theo.

* ,, *campestris* Leic.

* ,, *metatarsata* Edw.

Orthopodomyia maculipes Theo.

Armigeres obturbans (Walk.).

Ædes (*Stegomyia*) *aegypti* (L.).

,, ,, *albopictus* (Skuse).

Mansonia (*Mansonioides*) *indiana* Edw.

* ,, ,, *bonnae* Edw.

,, ,, *annulipes* (Walk.).

**Ædomyia venustipes* (Skuse).

Lutzia fuscana (Wied.).

,, *halifaxi* (Theo.).

**Culex bitaeniorhynchus* Giles.

* ,, *sinensis* Theo.

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* These species do not appear to have been recorded from Siam previously.

Ædes (Stegomyia) w-albus Theo.
" *(Skusea) furvus* Edw.
" *(Ochlerotatus) vigilax* (Skuse).

* " *(Banksinella) lineatopennis* (Ludl.).
**Ficalbia luzonensis* (Ludl.).
Mansonia (Coquillettidia) ochracea (Theo.).
" " *giblini* (Taylor).
Mansonia (Mansonioides) uniformis (Theo.).
Mansonia (Mansonioides) annuliferus (Theo.).

Culex sitiens Wied.
* " *vishnui* Theo.
* " *tritaeniorhynchus* Giles var. n. *siamensis*.
* " *whitei* Barraud.
" *gelidus* Theo.
" *fatigans* Wied.
" *fuscocephalus* Theo.
" *brevipalpis* (Giles).
" *(Culiciomyia) pallidothorax* Theo.

* " " *nigropunctatus* Edw.
* " *(Lophoceratomyia) rubithoracis* Leic.

Megarhinus splendens Wiedemann. (*Culex*). 1819.

Stanton (1920). Bangkok, larvæ found in artificial collections of water, x-xi. 1915 (as *Toxorhynchites immisericors* Walk.).

Sinton (coll. 1930): Bangkok, Palace Gardens, 1 ♂, 9. xii. 1930.

Megarhinus magnificus Leicester. (*Teromyia*). 1908.

Edwards.† Bangkok, 1913 (Dr. A. C. Rankin).

Uranotænia atra Theobald, 1905.

Stanton (1920). Bangkok, adults taken in houses, x-xi. 1915 (as *U. cancer* Leic.).

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 1 ♂, 3 ♀ ♀ caught in bedroom, xii. 1930.

Uranotænia campestris Leicester, 1908.

Sinton (coll. 1930). Near Chumphon, 1 ♂, 1 ♀ caught in train near light, 21. xii. 1930.

Uranotænia metatarsata Edwards, 1914.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 1 ♂, 1 ♀ caught in bedroom, xii. 1930.

Orthopodomyia maculipes Theobald, 1910.

Edwards (1928). Nakon Sri Tamarat, Khao Ram, 750—1,200 ft. 23. ii. 22. (Pendlebury), 1 ♀.

* These species do not appear to have been recorded from Siam previously.
† Private communication.

Armigeres obturbans Walker. (*Culex*). 1860.

Stanton (1920). Bangkok, larvæ found in both artificial and natural collections of water, x-xi. 1915.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 1 ♀ caught in bedroom, xii. 1930.

Edwards.* Bangkok (Laddell).

Ædes (Stegomyia) ægypti Linneaus. (*Culex*). 1762.
[*Stegomyia fasciata* (F.).]

Theobald (1910). Prapatom, 15—29. iii. 1907 (Dr. P. G. Woolley).

Stanton (1920). Bangkok, adults caught in houses, and larvæ found in artificial collections of water, x-xi. 1915.

Ædes (Stegomyia) albopictus Skuse. (*Culex*). 1894.

Theobald (1901). Siam (Skeate) (as *S. scutellaris*).

Stanton (1920). Adults caught in houses, and larvæ found in artificial collections of water, x-xi. 1915; Krabin and Koh Chang Island (as *S. albopicta*).

Ædes (Stegomyia) w-albus Theobald, 1905.

Stanton (1920). Bangkok.

Ædes (Ochlerotatus) vigilax Skuse. (*Culex*). 1889.

Edwards.* Patani, x. 1901 (Robinson & Annandale).

Ædes (Banksinella) lineatopennis Ludlow. (*Taeniorhynchus*) 1905.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 1 ♀ caught in bedroom, xii. 1930 ; near Chumphon, 1 ♂ caught in train near light, 21. xii. 1930.

Ædes (Skusea) furvus Edwards, 1928.

Stanton (1920). Krabin; Koh Chang Island; Koh Mohsi Island; Koh Kra Island; Koh Klun Island; Koh Rang Island; Koh Kut Island; (as *Stegomyia fusca* Leic.).

Ficalbia luzonensis Ludlow. (*O'Reillia*). 1905.

Sinton (coll. 1930). Chiengmai, 2 ♂ ♂, 2 ♀ ♀ bred from pupæ from old rice-field, 16. xii. 1930.

Mansonia (Coquillettidia) ochracea Theobald. (*Taeniorhynchus*). 1903.

Edwards.* Biserat, x. 1901 (Robinson & Annandale).

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* Private communication.

Mansonia (Coquillettidia) giblini Taylor. (*Pseudotaeniorhynchus conopas* var. *giblini*) 1914.

Edwards (1928). Nakon Sri Tamarat, Rompibun, 6. iii. 22. (Pendlebury), 1 ♀.

Mansonia (Mansonioides) uniformis Theobald. (*Panoplites*). 1901.

Stanton (1920). Bangkok, adults taken in houses, x-xi. 1915.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 6 ♂ ♂ 14 ♀ ♀ caught in bedroom, xii. 1930 ; near Chumphon, 3 ♀ ♀ caught in train near light, 21. xii. 1930. The identification of these 23 specimens has been checked by examination of the genitalia.

Edwards.* Bangkok (Laddell).

Mansonia (Mansonioides) annuliferus Theobald. (*Panoplites*). 1901.

Stanton (1920). Bangkok, adults taken in houses, x-xi. 1915.

Mansonia (Mansonioides) indiana Edwards, 1930.

Edwards (1930). Bangkok, ♀ ♀ in British Museum (Laddell, Stanton).

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 2 ♂ ♂, 2 ♀ ♀ caught in bedroom, xii. 1930. Mounts of the genitalia of the four specimens have been compared with the figures and descriptions given by Bonne-Wepster (1930) [as *Taeniorhynchus* (*Mansonioides*) *africanus* Theo.].

Mansonia (Mansonioides) bonnæ Edwards, 1930.

Sinton (coll. 1930). Near Chumphon, 1 ♀ caught in train near light, 21. xii. 1930. The specimen is somewhat rubbed and resembles *Mansonia annulipes* (Walk.) in general appearance, the genitalia are however different and agree fairly closely with the figure given by Bonne-Wepster (1930) (as *Taeniorhynchus* (*Mansonioides*) *annulipes* var. A.).

Mansonia (Mansonioides) annulipes Walker. (*Culex*). 1857 (*Culex longipalpis* v. d. Wulp.)

Stanton (1920). Bangkok, adults taken in houses, x-xi. 1915.

Sinton (coll. 1930). Near Chumphon, 1 ♀ caught in train near light, 21. xii. 1930. The genitalia agree with the figure given by Bonne-Wepster (1930).

Ædomyia venustipes Skuse. (*Ædes*). 1889.

Sinton (coll. 1930): Bangkok, Phya Thai Hotel, 1 ♀ caught in bedroom, xii. 1930. Near Utaradit, 1 ♀ caught in train, 18. xii. 1930.

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* Private communication.

Lutzia fuscana Wiedemann. (*Culex*). 1821.

Theobald (1910): Prapatom, viii. 1906 (Dr. P. G. Woolley) (as *Culex concolor*).

Stanton (1920): Bangkok, adults caught in houses, and larvæ in natural collections of water, x-xi. 1915 (as *C. concolor*).

Sinton (coll. 1930): Bangkok, Phya Thai Hotel, 1 ♀ caught in bedroom, xii. 1930; Ayudhya Railway Station,* 1 ♀ caught 5. xii. 1930; Chiengmai, one larva from old ricefield 16. xii. 1930; near Chumphon, 1 ♀ caught in train near light, 21. xii. 1930. The three adults agree with the form found commonly in India.

Edwards.† Bangkok (Laddell).

Lutzia halifaxi Theobald. (*Culex*). 1903.

Stanton (1920): Bangkok, adults taken in houses, and larvæ found in artificial collections of water, x-xi. 1915 (as *Culex halifaxi*).

Culex sinensis Theobald. (*Culex gelidus* var. *sinensis*). 1903.

Sinton (coll. 1930): near Chumphon, 1 ♂ caught in train near light, 21. xii. 1930. The genitalia have been examined.

Culex bitæniorhynchus Giles, 1901.

Sinton (coll. 1930): Bangkok, Phya Thai Hotel, 1 ♀ caught in bedroom, xii. 1930; Chiengmai, 1 ♂ bred from larva from old ricefield, 18. xii. 1930, six larvæ from the same field, and 1 ♂ bred from larva from foothill stream, 17. xii. 1930; near Lopburi Railway Station,* 1 ♂ caught in train, 15. xii. 1930; near Utaradit Railway Station, 1 ♀ caught in train, 18. xii. 1930; Lampang Railway Station, larvæ in hoof-marks near borrow-pits, 18. xii. 1930. All the adults are darker in colour than the common form of this species occurring in India, the two specimens bred at Chiengmai are of the variety *ambiguus*, the other three are of the type form.

Culex gelidus Theobald, 1901.

Stanton (1920): Bangkok, adults caught in houses, and larvæ from natural collections of water, x-xi. 1915.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 7 ♂ ♂, 9 ♀ ♀ caught in bedroom, xii. 1930; Bangkok, Oriental Hotel, 1 ♀ caught 7. xii. 1930; Chiengmai 1 ♂, 1 ♀, bred from larvæ from old ricefield 17. xii. 1930; near Chumphon, 1 ♀ caught in train near light, 21. xii. 1930. A number of the specimens have two dark spots within the pale area of the mesonotum, and in the majority the abdominal bands are triangularly produced in the middle to a greater or less extent.

* North of Bangkok.

† Private communication.

Culex sitiens Wiedemann, 1828.

Stanton (1920): Bangkok, adults taken in houses, x-xi. 1915.

Edwards (1928). Nakon Sri Tamarat, Khao Luang, 2,000 ft. 29. iii. 22. (Pendlebury) 1 ♀. The occurrence of this salt marsh species at such an altitude is probably to be explained by the fact that a north-east monsoon was blowing at the time of its collection.

Culex vishnui Theobald, 1901.

Sinton (coll. 1930): Bangkok, Phya Thai Hotel, 2 ♂ ♂ caught in bedroom, xii. 1930, and a number of ♀ ♀ probably conspecific, but these are difficult to separate with certainty from the ♀ ♀ of the variety referred to below, and from that sex of *Culex whitei* Barraud. The ♂ ♂ agree in markings and in the structure of the genitalia with the common Indian form.

Culex tritaeniorhynchus Giles, 1901, var. n. **siamensis.**

Sinton (coll. 1930): Bangkok, Phya Thai Hotel, 6 ♂ ♂ caught in bedroom, xii. 1930; near Utaradit, 1 ♂ caught in train, 8. xii. 1930; near Chumphon, 2 ♂ ♂ caught in train near light, 21. xii. 1930; Chiengmai, 8 ♂ ♂ bred from larvæ from old ricefield, 17. xii. 1930; Lopburi Railway Station, 2 ♂ ♂ caught in waiting room, 15. xii. 1930; Bang Pa-In Railway Station,* 1 ♂ caught in room, 15. xii. 1930; also a number of ♀ ♀ from the same localities probably conspecific.

As regards markings, coloration, wing scaling and venation, these specimens are fairly typical of the species. The mesonotal scales, in some specimens, are rather lighter in colour than in others from more western localities, but variation in this direction is known to exist. The male genitalia however more nearly resemble those of *C. vishnui* in structure, and, when an examination was first made, it was thought that the specimens represented a variety of that species. Some males were sent to Mr. F. W. Edwards, of the British Museum, and he is of the opinion that they are *C. tritaeniorhynchus*, or a variety of that species. The teeth on the lateral plate of the phallosome are strongly curved at their bases, the tips directed apically, one tooth rather longer than the others, but shorter than in *C. vishnui*, the tip hardly projecting beyond the apical margin of the lateral plate. In Indian specimens of *C. tritaeniorhynchus* the corresponding teeth are all about the same length, are less curved at their bases, and are directed laterally. The collection did not include any isolated larval skins of this species, but 11 larvæ resembling that of *C. tritaeniorhynchus* were collected, 10 at Chiengmai, 9 of which were found in a fallow rice field, and one in a hill stream; one other was taken from a weedy canal in Bangkok. These may include larvæ of *C. whitei* Barr. which is at present unknown.

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* West of Bangkok.

Culex whitei Barraud, 1923.

Sinton (coll. 1930). Chiengmai, 3 ♂ ♂ bred from larvæ from old ricefield, 17. xii. 1930, also some ♀ ♀ probably conspecific. The ♂ ♂ agree in hypopygial details with the original specimens described from Assam; the ♀ ♀ cannot with certainty be distinguished from that sex of *C. vishnui.*

Culex fuscocephalus Theobald, 1907.

Stanton (1920). Bangkok, adults taken in houses, x-xi. 1915.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 1 ♀ caught in bedroom, xii. 1930; near Tung Song Junction, 1 ♀ caught in train, 2. xii. 1930; Chiengmai, 1 ♂, 1 ♀ bred from larvæ from old ricefield 16. xii. 1930; near Chumphon, 1 ♂, 1 ♀ caught in train near light, 21. xii. 1930.

Culex fatigans Wiedemann, 1828.

Theobald (1910). Prapatom, viii. and ix. 1906, 10—18. i. 1907, 19. iii. 1907, 30. xii. 1907 (Dr. P. G. Woolley).

Stanton (1920). Bangkok, adults taken in houses, and larvæ from natural and artificial collections of water, x-xi. 1915.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, many adults caught in bedroom, xii. 1930; Rajburi Railway Station, 1 ♂, 3. xii. 1930; Lampang Railway Station, 1 ♂, 1 ♀, 15. xii. 1930; near Lopburi Railway Station, 1 ♀ caught in train, 15. xii. 1930; Chiengmai, 1 ♂, 3 ♀ ♀ taken in houses, 16. xii 1930; Chiengmai Leper Asylum, 2 ♂ ♂, 3 ♀ ♀, 16. xii. 1930; near Chumphon, 1 ♂, 2 ♀ ♀ caught in train near light, 21. xii. 1930.

Culex brevipalpis Giles. (*Stegomyia*). 1902.

Stanton (1920). Bangkok, larvæ taken from artificial collections of water, x-xi. 1915 (as *Cyathomyia brevipalpis*).

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 2 ♂ ♂. 8 ♀ ♀ caught in bedroom, 3. xii. 1930; Chiengmai, 1 ♀, 16. xii. 1930.

Culex (Culiciomyia) pallidothorax Theobald, 1905.

Edwards.* Dai su tep. 1250 meters, x. 1914. Specimen in Brit. Mus.

Culex (Culiciomyia) nigropunctatus Edwards, 1926.

(*Culex pullus* Edw. nec. Theo.)

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 4 ♀ ♀ caught in bedroom, xii. 1930; near Chumphon, 1 ♀ caught in train near light, 21. xii. 1930.

* Private communication.

Culex (Lophoceratomyia) rubithoracis Leicester, 1908.

Sinton (coll. 1930). Bangkok, Phya Thai Hotel, 1 ♂, 4 ♀ ♀ caught in bedroom, xii. 1930; near Chumphon, 2 ♂ ♂ caught in train near light, 21. xii. 1930.

Note.—With regard to three species mentioned below, which were recorded from Siam in Edwards (1922), Mr. Edwards has informed me in a private communication that this was done from specimens in the British Museum labelled Talum, Siam. According to Pendlebury (*Jour. F. M. S. Mus.* **14,** Part 3, 1928) the labelling is incorrect, the locality being Lubok, Tamang, Pahang, F. M. S. The species are:—*Armigeres* (*Leicesteria*) *flavus* (Leic.), *Armigeres* (*L.*) *annulitarsis* Leic. and *Aedes* (*Aedimorphus*) *alboscutellatus* (Theo.).

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CHANGES IN THE AMOUNT OF BLOOD SUGAR IN MALARIA.

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IN recent years considerable attention has been directed to the changes in the amount of blood sugar which occur in certain acute infections. Observations on these changes have been recorded in various protozoal diseases, more especially in trypanosomiasis and bird malaria. This is a subject which is of much interest in human malaria, for it is well known that glucose is essential for the culture of human malarial parasite *in vitro,* that the amount of blood sugar may influence the clinical course of malaria, that quinine has, in medicinal doses, the property of lowering the percentage of blood sugar and that in protein shock, which closely resembles the malaria paroxysm, there is an increase of blood sugar.

Although several workers have reported on this subject there is a considerable diversity in the results recorded. A series of experiments have been conducted in an attempt to correlate, if possible, the findings of these workers and to obtain more complete information on the subject.

Methods of research.

The researches aimed at an estimation of the blood sugar before, during and after the malarial paroxysm in as many patients as possible. It was, however, found very difficult to obtain a continuous series of observations in a large number of cases, under conditions which were uninfluenced by the action of diet, or drugs*. In many instances when estimations were done during apyrexia,

* Hughes (1925) has shown that quinine in medicinal doses causes a hypoglycæmia in man.

no fever occurred before it became necessary to start treatment, while other patients were seen first during pyrexia and others only after it had subsided.

The method used for the estimation of the blood sugar was that devised by Maclean (1922). This method was modified in that instead of filtering the deproteinised blood through Whatman's filter paper, it was centrifugalised for 5 minutes at 3,000 revolutions per minute and 20 c.cs. of the clear supernatant liquid pipetted off. By this means time was saved and the loss of fluid in filtration avoided.

Results of the investigation.

The amount of blood sugar in persons in tropical climates seems to vary considerably from that seen in more temperate zones, so before making any deductions from the results, it was necessary to determine what is the normal range of blood sugar in apparently healthy individuals living under the same conditions. For this purpose 26 British soldiers, living under the same conditions as the patients, were examined and the blood sugar was found to range between 0·071 and 0·101 per cent with an average of 0·085 (standard deviation 7·8). Among 20 Indian prisoners the figures were 0·096 and 0 107 with a mean of 0·101 per cent (standard deviation 3·2).

The more complete investigations were carried out at Kasauli on young British soldiers suffering from chronic infections with *P. vivax* and *P. falciparum*. These patients had histories of several previous attacks of the disease but had had no relapse for some time. None of them had any specific treatment for malaria for a considerable period, usually several weeks, before the estimations were carried out.

The patients all showed parasites in the peripheral blood at the time when the first estimations were made and these were carried out three or four hours after the last meal.

The individual estimations may be classified as follows:—

(*i*) Soon after the discovery of the parasites in the peripheral blood.
(*ii*) At the time of fever.
(*iii*) After the fever had subsided.
(*iv*) At the completion of specific treatment (usually a three-weeks course of quinine and plasmoquine in benign tertian and one week in malignant tertian malaria).

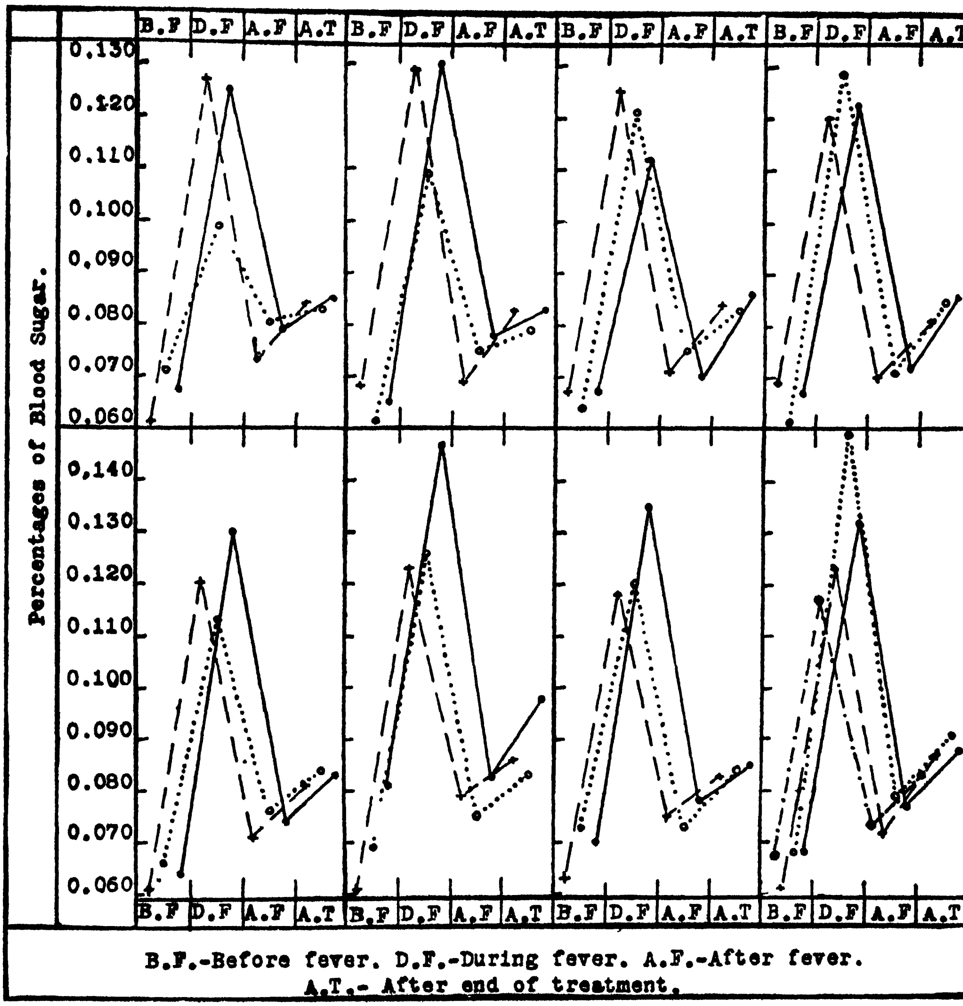
In 25 patients suffering from infections with *P. vivax*, it was possible to make estimations in all the four different periods. In 14 cases the original estimations were made within 5 hours of the occurrence of fever and the others about 24 hours previous to it. The observations after fever were usually carried out 12–18 hours after the pyrexia had finished.

The results of these estimations have been shown graphically in Text-Fig. No. 1. The average level of the blood sugar before pyrexia was 0·066 per cent (max. 0·081; min. 0·061); during pyrexia 0·124 per cent (max. 0·149; min.

0·099); after the fever 0·075 per cent (max. 0·083; min. 0·069) and after the end of treatment 0·085 per cent (max. 0 098; min. 0·079). These figures show a distinct rise of the blood sugar during pyrexia and in 16 cases, or 64 per cent, there was hyperglycæmia, if 0·120 per cent is taken as the lower limit of this condition.

Text-Figure No. 1.

Blood-sugar level in relation to fever in 25 cases of benign tertian malaria.



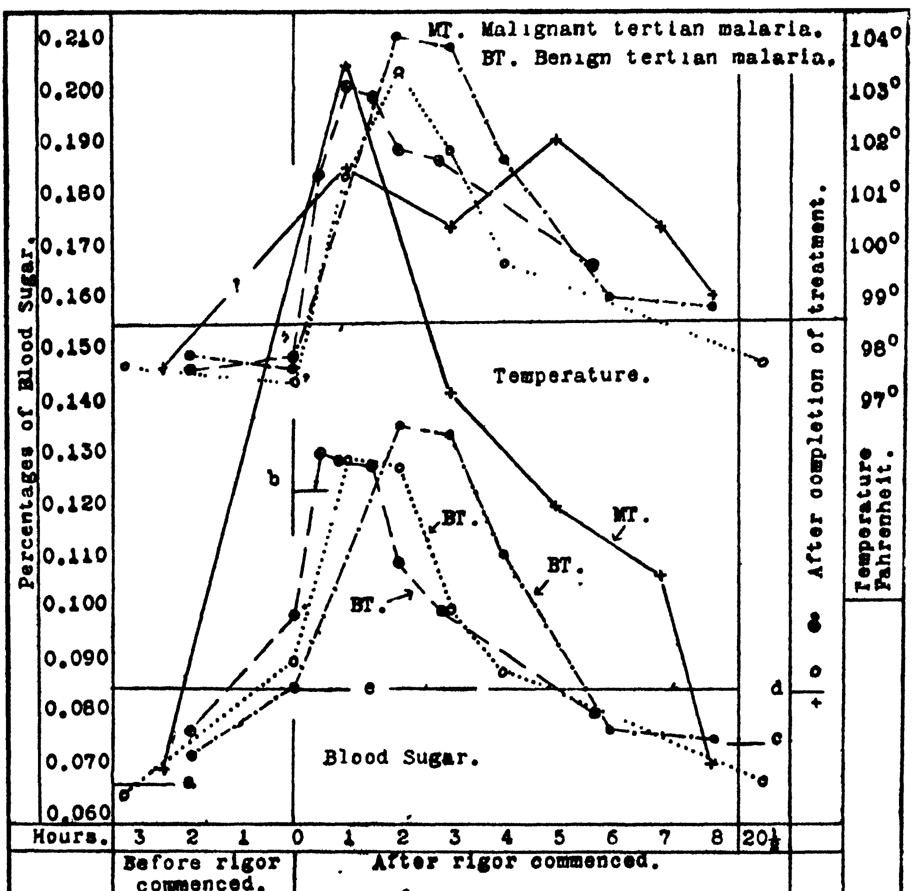
The results of the examination of three other benign tertian infections, in which more frequent estimations were made during pyrexia, are shown in Text-Figure No. 2. The same rise of blood sugar during pyrexia was found.

In addition to these patients various estimations were made at different times in 38 other British cases with *P. vivax* infections. It was not found

possible to obtain a complete series of observations in each of these patients. Of 27 patients examined before pyrexia, the average blood sugar was 0·068 per cent (max. 0·073; min. 0·061). Eleven patients examined during pyrexia had an average of 0·123 per cent (max. 0·143; min. 0·110). In the same number examined after the fever had subsided the average was 0·075 per cent (max. 0·089; min. 0·069), while 30 cases examined at the end of treatment showed an average of 0·085 per cent (max. 0·093; min. 0·079).

Text-Figure No. 2.

Blood-sugar level in relation to the paroxysm in malaria.



Benign tertian malaria. "a". Average of 55 cases before fever- 0.067. "b". Av. of 39 cases during fever- 0.124. "c". Av. of 39 cases 12-18 hrs. after fever- 0.075. "d". Av. of 58 cases after completion of treatment- 0.085. "e". Av. of 26 normal cases-0.086

If the results of all these benign tertian infections be combined it is found that of 55 patients examined before fever the blood sugar averaged 0·067 per

cent (standard deviation 4·6), of 39 during pyrexia it averaged 0·124 per cent (standard deviation 9·8), of 39 after the fall of fever it averaged 0·075 per cent (standard deviation 4·9) and in 58 seen after completion of treatment the average percentage was 0·085 (standard deviation 4·3).

The results of 7 estimations of the blood sugar in a British patient suffering from infection with *P. falciparum* are shown in Text-Figure No. 2. Here the percentage of blood sugar rose to 0 206 during pyrexia. In another case the percentages before, during and after fever, and after treatment were 0·065, 0·140, 0·071 and 0 081 per cent respectively. While in two other cases taken before and after a week of treatment, the figures were 0·071 and 0·075 per cent before as compared with 0·081 and 0·090 afterwards.

All the cases mentioned above were diagnosed by blood examination, but in addition to these a series of Indian patients were examined, in whom the diagnosis was, in the majority of instances, made on clinical symptoms alone. These patients were examined in Lahore at a time when the autumnal wave of malignant tertian malaria was occurring and were probably in most cases suffering from fresh infections with *P. falciparum*. Because of the nature of the diagnosis these figures have not the same value as those in which the infections were verified by blood examination. They are, however, of interest as showing the rise in blood sugar which occurs during pyrexia, probably malarial. The blood of these patients was taken after a fast of about 12 hours and all the cases had fever when the estimations were made.

The results are shown graphically in Text-Figure No. 4. The average percentage of blood sugar among the 57 patients examined was 0·134 (max. 0·184; min. 0 105).

Observations by other workers.

Several other workers have recorded estimations of the blood sugar in malaria. Some of these observations have been made at different periods in the same patient during an acute attack while others are simply single records at some time during an infection.

De Langen and Shut (1918), working with benign tertian infections in the Dutch East Indies, found that a slight decrease in the amount of blood sugar often occurs 3-4 hours before an attack, then about 1 hour before the paroxysm it begins to rise as much as 0 06 mgrms. per cent or even more. Once they found the percentage as high as 0 270. This high level of blood sugar continues during the rise in temperature and then falls again, but the decrease precedes the fall in temperature. Generally it was observed that the level of the blood sugar was low in the fever-free days. The results in 8 cases have been charted by them, and the maximum amounts of blood sugar during pyrexia lay between 0·170 and 0·270 per cent with an average of about 0·190 per cent. They think that figures more than 0 180 per cent indicate a hyperglycæmia and this occurred during fever in four of their eight cases.

From investigations in Formosa, Yoshida and Kô (1920) report that during the apyrexial periods of malarial infections the amount of blood sugar lay within normal limits, i.e., on an average 0 09 per cent in benign tertian, 0·082 in quartan and 0 093 in malignant tertian malaria. They found that during pyrexia the amount of blood sugar rose to a maximum of from 0 120 to 0·158 per cent. The average figure in this period in benign tertian fever was 0 117 per cent and in malignant tertian 0·125, while in a case of blackwater fever it was found to be as high as 0 133 per cent.

Boulay and Leger (1923), at Dakar, examined one case of benign tertian malaria, one of quartan and eight of malignant tertian. They report at the time of the paroxysm a slight insufficiency of the glycogenic function of the liver as shown by a small rise in blood sugar which lasted 2-5 days.

In Indo-China Borel, Pons, Advier and Guillerm (1923) made a number of estimations of blood sugar in malarial cases. The average amount of blood sugar found in 5 normal persons was 0 069 per cent (max. 0 083; min. 0 050). Twenty-three cases of infection with *P. falciparum* gave an average of 0 103 per cent (max 0 175; min. 0 050). The average in eight cases of benign tertian malaria was 0 103 per cent (max. 0 166; min. 0 071), while in four quartan cases it was 0 070 per cent (max. 0 110; min. 0 037). Among the malignant tertian infections the percentages were in 9 cases more than 0 120, in 12 more than 0 100, while in 5 they were below the local average of 0 069. Among the *P. vivax* infections the percentage was once greater than 0 120, in four cases more than 0 100 and none below 0 069, while in quartan three were below 0 100 and two below 0 069. These workers consider hyperglycæmia the rule if one takes 0 069 per cent as the normal local constant. They do not think that the race, age and sex of the patient had any influence nor the stage of the parasite in the peripheral blood. The species of parasite, however, seemed to have some influence.

Massa (1927) examined 28 malarial patients and reports that when fever is absent the blood-sugar content is about normal. In fresh infections and relapses following a long apyretic interval, it is especially noteworthy that the amount of blood sugar rises rapidly during the rigor, becoming normal at the height of the fever and subnormal at the beginning of apyrexia. If relapses are numerous and close together, the alteration in blood sugar is insignificant.

Piana (1928) investigated the blood sugar in children of 7 years or less in age. In three ordinary cases of malaria the sugar was between 0 145 and 0·156 per cent, while in four 'pernicious' cases (i.e., with meningeal symptoms) the figures given are 0 197, 0 287, 0 400 and 0 400 per cent. He concludes that in general there is a sharp increase in grave cases.

MacDougall (1930) reports that in one case of malaria examined the blood sugar was increased during the paroxysm of chill, etc.

Anderson (1927) states that Cumston (1920) reported a hyperglycæmia at the onset of the cold stage and that this diminished with the full development of the rigor. The former author says that he has confirmed these

observations and that a hyperglycæmia, not often exceeding the average kidney threshold (0·180 per cent) but occasionally doing so, was usually found at the onset of the cold stage. It rapidly diminished with the approach of the hot stage, at the height of which the blood sugar was often a little, sometimes much, below the normal fasting level (0·10 per cent).

Ruge, Lohfeldt, Knabe, Eisenberg and Kunert (1929) have made determinations of the blood sugar in 140 cases, and have tabulated their results as follows:—

Type of malaria.	Total number of cases.	Number examined during fever.	Limits of blood sugar.	Mean.	Number examined during apyrexia.	Limits of blood sugar.	Mean.	Total examinations.
Quartan ..	3	1	90	90·0	2	94–106	96	4
Benign tertian ..	15	3	91–101	97·5	12	69–120	90	18
Malignant tertian	73 *	11	91–105	94·3	62	54–120	97	83
Old malaria ..	49	1	93	93·0	48	39–115	115 †	52
TOTAL ..	140	16	90–105	94·0	124	54–120	98	157

* One case of blackwater fever. † *Sic!*

They conclude that an increase in blood sugar only occasionally occurs in malaria, and it does not go above 130 mg. per cent. Cases higher than 120 mg. per cent were found in benign tertian (febrile) once with 0·124, twice each in malignant tertian (with and without fever) 0 127, 0·122, 0·123, 0·160 per cent. The last case had fallen to 0·086 ten days later.

Most of the above observations point to an increase of blood sugar during pyrexia in malaria but Petersen (1926) says that in the fasting patient the period of the chill and rise of temperature is associated with a decrease in blood sugar and with the crisis and fall in temperature the blood sugar again increases. Rudolf and Marsh (1927) and Rudolf (1927) report that in experimental infections with *P. vivax* for the treatment of general paresis, the blood-sugar level varies inversely with the temperature.

Several workers have reported isolated estimations of the blood sugar in malaria. These have been chiefly in connection with tests for liver efficiency. Sinton and Hughes (1924) record the blood sugar in 15 Indians showing *P. falciparum* in their peripheral blood at the time, and of whom only one had fever. Here the average was 0 104 per cent (max. 0·146; min. 0·075). In 10 cases the percentage was above 0·100 and in only one above 0·120. Hughes (1925) and Hughes and Malik (1930) have given the blood-sugar content in

9 cases of 'chronic malaria.' The average is 0·123 per cent (max. 0·162; min. 0·098) and all the cases but one had a percentage greater than 0·100, while 5 were above 0·120.

Green (1929) gives the records of blood sugar in 21 cases of malaria, tested for liver efficiency. In eight patients with benign tertian malaria the average was 0·110 per cent (max. 0·140; min. 0·075) and of these six were over 0·100 while two were greater than 0·120. Among nine cases of malignant tertian malaria the average was 0·112 per cent (max. 0·133; min. 0·092), while seven exceeded 0·100 per cent and three 0·120 per cent. In four quartan cases the average was 0·111 per cent (max. 0·117; min. 0·100) and of these three were over 0·100 per cent and none over 0 120.

Discussion of results.

De Langen and Shut (1918) record a fall in the blood-sugar level 3 or 4 hours before the paroxysm, with a rise about one hour before the rigor. This rise reaches its maximum during the pyrexia and falls again more rapidly than the temperature, while in the apyrexial interval the blood-sugar level is low. Anderson (1927) and Cumston (1920) also report hyperglycæmia at the commencement of the cold stage, but state that it diminishes rapidly with the approach of the hot stage. Many of the authors, whose work has been summarized above, also found a rise in the blood-sugar level during fever. On the other hand, Petersen (1926) and Rudolf and Marsh (1927) report that in their cases the blood sugar varied inversely with the temperature.

The observed oral temperature in relation to the percentage of blood sugar has been charted in Text-Figure No. 2 for three cases of benign and one of malignant tertian malaria. Text Figure No. 1 shows the recorded percentages of blood sugar before, during and after the rigor in 25 infections with *P. vivax.*

If the results in Text-Figure No. 1 be examined it will be seen that the records made a few hours before fever are lower than those taken afterwards in the apyrexial interval. This would support the view of de Langen and Shut that there is a fall in blood-sugar level a few hours before the rigor.

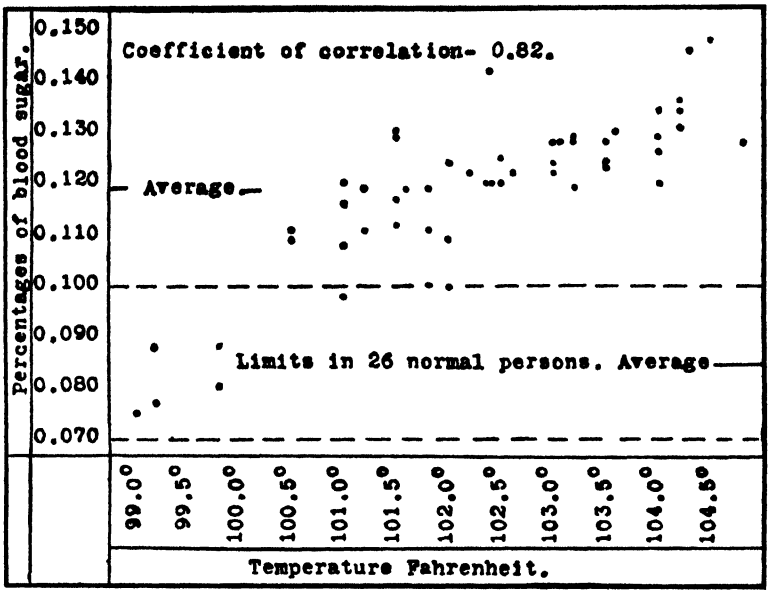
The few cases recorded in Text-Figure No. 2 suggest that the blood sugar begins to rise again a short time before the oral temperature does. It must be remembered that at the beginning of the cold stage of the paroxysm, although the oral temperature may be normal or subnormal, yet the internal temperature has already begun to rise, so it is probable that the early rise in blood sugar is more closely related to the true or internal temperature of the body than one would suppose from the records of oral temperature.

With regard to the febrile stage in chronic benign tertian malaria, the results shown in the Text Figures mentioned above indicate that during the pyrexial period there is a marked rise in the blood-sugar level, often exceeding 0·120 per cent.

In Text-Figure No. 3 the percentages of blood sugar observed in 52 cases of chronic benign tertian infection have been charted against the observed oral temperatures. For this there will be seen that a marked correlation was found between these two factors, the coefficient of correlation being 0·82. The results

Text-Figure No. 3.

The relation between blood-sugar level and temperature in 52 cases of benign tertian malaria.



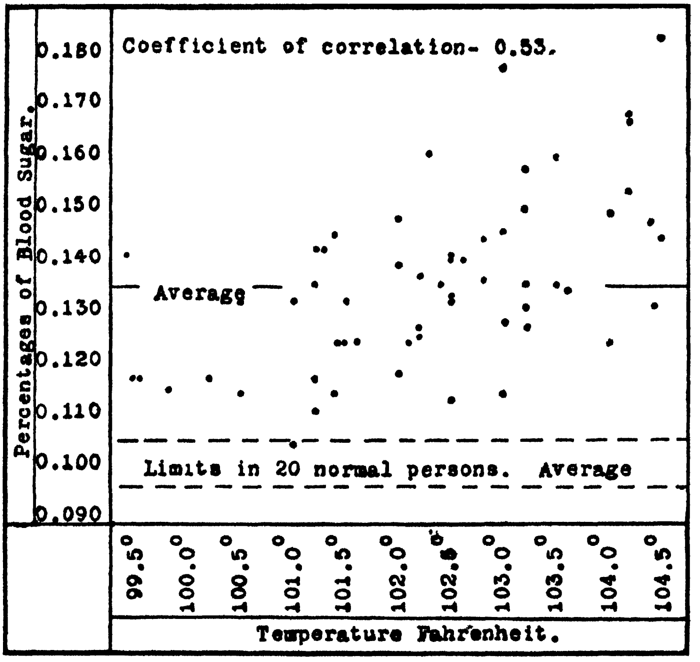
in 57 cases of 'clinical malaria,' probably mainly malignant tertian, are shown in Text-Figure No. 4. These Figures do not show any marked relationship and the coefficient of correlation is only about 0·53.

These findings might suggest that there is not such a marked relationship between the blood-sugar level and the temperature in malignant tertian as compared with chronic benign tertian malaria. There are, however, several reasons which prevent one drawing any definite conclusions in the matter. The cases of 'clinical malaria' were not diagnosed by blood examination and so may have included some other acute fevers as well as malaria. The degree of rise in blood sugar may vary in the different kinds of malaria infection (*vide infra*) and there is no evidence to show the only type of malaria present was malignant tertian. Another factor which may influence markedly the relationship between blood sugar and temperature would be, as noted above, that the blood sugar in the early part of the attack rises more rapidly than the fever and declines more rapidly in the later stages. Under such conditions the relationship between the oral temperature and the blood-sugar level might be different in the early and in the late stages of the paroxysm. So observations made in the former period

might show a correlation to each other and similarly those in the latter, but mixed records might not do so. In this connection it is interesting to note that practically all the benign tertian estimations were made in the early part of the attack, while the 'clinical' cases were examined at many different periods. This may account for the differences in the results observed.

Text-Figure No. 4.

The relation between blood-sugar level and temperature in 57 cases of 'clinical' malaria.



It was pointed out by Sinton, Harbhagwan and Jaswant Singh (1930) that their results in determining the pyrogenic limit of parasites in chronic benign tertian malaria, suggested that the toxic effects of the parasites in these infections might have reached a more or less fixed or constant condition. This might also be an explanation of the close correlation between blood-sugar level and temperature found by us in such chronic infections.

The degree of the rise of blood sugar and its duration during pyrexia in any one case would probably depend primarily on the amount of glycogen available in the liver. One would therefore expect a more marked and prolonged rise in fresh infections and in relapses after a long apyrexial interval than in cases where the attacks were numerous and close together, and in which the glycogen store in the liver was consequently at a low ebb. The observations of Sinton and Hughes (1924), of Monteleone (1924), of Williams (1927) and of Green (1929) show that in many cases of malaria there is a diminished

power of storage of glucose in the liver, so in malarial infections one would not expect to have such a large glycogen reserve as normal to call upon. The findings reported by Massa (1927) support such a view.

It is interesting to note that in the chronic cases of malaria examined by Hughes and Malik (1930) the average level of the blood sugar was much higher than the average found by us in normal persons or by Sinton and Hughes (1924) in fresh infections. Was this due to the fact that a greater damage to the liver in these cases prevented a rapid assimilation of ingested carbohydrate and the blood-sugar level remained high for longer periods afterwards ?

When treatment had been finished it is seen that the blood sugar had returned to a higher level than in the interpyrexial period. This was probably due to a return of the liver to its normal condition following on a cure of the disease, for it is well known that this organ has remarkable recuperative powers.

The results recorded by Petersen (1926) and Rudolf and Marsh (1927) in cases with general paresis are difficult to understand. The glucose tolerance tests carried out by the last authors suggest that the liver in this disease may show some damage of its glycogenic function before malarial infection. It seems possible that such damage from previous syphilis or from anti-syphilitic treatment may be in some degree responsible for the results, in delaying the response to the paroxysm. Another possible explanation is that the damaged nervous system in general paresis may not react so rapidly and there may be a delay in the arrival of the nerve stimulus at the adrenal glands (*vide infra*).

The more rapid fall of the blood sugar during pyrexia recorded by Cumston (1920) and Anderson (1927), as compared with our results, requires explanation. This may have been due to the fact that our cases were strong well-nourished adults, in whom one would expect a good glycogen reserve and this had not been depleted by recent attacks of malaria, for most of them had been examined in the first pyrexia after a very long. fever-free interval. If the patients examined by the authors mentioned were ill-nourished or had had several recent attacks of fever, one would not expect a large glycogen reserve and hence the rise in blood sugar might terminate more quickly.

Our results would suggest that among this selected population of chronic benign tertian cases, the blood sugar is probably at a lower level than normal before the occurrence of a relapse, that there is a slight fall a few hours before fever begins to rise, that the sugar level rises more rapidly than the oral temperature and that it is high during the early part of the hot stage, but that it falls more rapidly than does the temperature. After a proper course of treatment, giving a cure rate of over 90 per cent, the blood-sugar level will return to normal.

In only two cases of malignant tertian malaria diagnosed by blood examination was the blood sugar estimated during pyrexia and the results were 0·206 and 0·140 per cent. Among the 57 'clinical' cases of malaria, many of whom must have had this type of fever, the average percentage of blood sugar during pyrexia was 0·134 and compared with 0·126 in 39 cases suffering from benign

tertian malaria. This suggests that the pyrexial limit of blood sugar in the former fever may be higher than in the latter. It must be remembered that the fever in chronic benign tertian malaria is much milder than in fresh infections with malignant tertian, and this difference in the nature of our cases may account for the different results. The results reported by Piana (1928) would support the idea that the rise is greater in more severe cases.

Suggestions as to the causes of the increase of blood sugar.

A rise in the blood-sugar level may be due to:—

(*a*) Excessive intake of carbohydrates.

(*b*) Defective storage of an ordinary intake.

(*c*) Defective utilization of the blood sugar by the tissues.

(*d*) Excessive glycogenolysis in the liver.

(*e*) A combination of several of these factors.

The possible effects of one or many of these factors in the production of a rise in the blood-sugar level in the malarial paroxysm must be discussed.

(*a*) *Excessive intake of carbohydrates.*

As there was no pre-paroxysmal intake of sugar, this factor had no influence.

(*b*) *Defective storage of an ordinary intake of carbohydrates.*

Sinton and Hughes (1924), Monteleone (1924), Williams (1927) and Green (1929) have all produced evidence to show that there is a deficiency in the storage capacity of liver for glucose during malarial infections. Under these conditions one would not be surprised to find a high initial level of blood sugar if the period of starvation before the estimation was not sufficiently long, but this would not account for a rise during the pyrexial period.

(*c*) *Defective utilization of sugar by the tissues.*

It is now recognized that insulin is essential for the utilization of sugar by the tissues. As a great deal of the segmentation of the parasites at the time of pyrexia takes place in the internal organs, including the pancreas, it is not beyond the bounds of possibility that the 'toxins' of the disease or the mechanical obstruction of the pancreatic vessels may interfere with the production of insulin.

Boliger and Hartman (1925) have shown that the ingestion of carbohydrates causes a lowering of the inorganic phosphates in the blood and urine and that the demand for these salts is only apparent when the pancreatic hormone is available and carbohydrate is being utilized. In the absence of this hormone the phosphate level is unaffected by the ingestion of carbohydrates. Craig (1909) states that the question of phosphates in the urine in malaria was studied by Rem-Picci, Bernasconi, Rosenstein, Gee and Freund. They all

agree in stating that at the beginning of the paroxysm there is a marked decrease in the phosphates of the urine, followed, during the apyrexia, by a marked increase in the excretion of phosphoric acids, thus proving that during fever there is a retention of phosphates in the body. The amount of phosphate excreted during the 24 hours by malarial patients is greater than normal. These findings suggest that insulin is probably being produced in excessive amounts to deal with the hyperglycæmia of pyrexia and that the increase in blood sugar is not due to a deficient production of this hormone.

Green (1929) also tested the pancreatic efficiency by various methods in 21 cases of malaria, and was unable to find any evidence of deficiency.

(*d*) *Excessive glycogenolysis in the liver.*

There are various factors present in the malarial paroxysm which might cause such a condition. It may be due to:—

(*i*) The increased metabolism of fever.
(*ii*) Damage to the liver cells by the infection.
(*iii*) An increased output of adrenalin.

(*i*) Increased metabolism of fever.

Du Bois (1922) has shown that during the malarial paroxysm the heat production may rise as much as 216 per cent over normal. The increased metabolism necessary to produce this extra heat would probably come from an increased oxidation. Since the carbohydrates are the most easily oxidized substances in the body, one would expect that there would be a call upon these to supply the demand and hence a rise in the circulating blood sugar, both for this purpose and to act as fuel for the complete combustion of fats and proteins. This increased demand would probably soon exceed the available mobile supply of sugar and so this might account for the fall in the level of the blood sugar before that of the temperature.

Another suggestion is that the rise in temperature might increase the rapidity of reaction between the liver enzymes and glycogen, but this would not explain the marked rise in blood sugar before the temperature was fully developed. Against temperature *per se* playing an important rôle is the fact that Jacobowsky (1923), in rabbits, found that heat puncture did not produce a hyperglycæmia, and he concluded that rise of blood sugar seen in ordinary fevers is not due to temperature alone but to the toxins of the diseases.

It might be suggested that the increased muscular action of the 'shiver' of the malarial paroxysm would call forth an increased production of sugar from the liver to supply the necessary energy to the muscles, but against such a suggestion is the fact that the rise of blood sugar in malaria may also occur in cases which show no distinct shiver.

The evidence available suggests that temperature *per se* does not play an important part in the causation of the rise of the blood-sugar level during the malarial paroxysm.

(*ii*) Damage to the liver cells by the infection.

At autopsy in acute cases of malaria the liver cells may show anything from cloudy swelling and fatty degeneration up to acute necrosis. Sinton and Hughes (1924), Monteleone (1924), Williams (1927) and Green (1929) have shown by lævulose and glucose tolerance tests that malaria has some damaging effect on the glycogenic function of the liver. That this injury to the liver parenchyma may cause a rise in blood sugar is suggested by the fact that Bodansky (1923) found that the initial effect of damage to the liver by chloroform, etc., is a hyperglycæmia, which disappears later and the blood sugar becomes subnormal.

Macleod (1926) states that glycogenolysis may be secondary to local asphyxia of the liver cells due to vaso-constriction. It is possible that some such local asphyxia may occur during the malarial paroxysm due to blocking of the vessels of the liver by the segmenting parasites or obstruction of their lumen by the swelling of the endothelial cells which is known to occur Anderson (1927) also thinks that the segmenting parasite with its poison may have a direct irritant action on the smooth muscle of the liver vessels

Langfeldt (1920) and Lesser (1921) have shown that a rise in the pH of the blood of the portal vessels causes an increased glycogenolysis, for this reason it seems probable that the lowered alkali reserve, which has been found in malaria by Sinton and Baily (1924), may help to account for the rise in blood sugar.

The above findings seem to show that damage to the liver cells may play some rôle in the rise in blood sugar in the malarial paroxysm.

(*iii*) An increased output of adrenalin

It is well known that an increase in adrenalin in the blood causes a rise in the blood-sugar level through glycogenolysis, and that the sympathetic nervous system has a marked influence in controlling the output of this hormone from the adrenal glands. There is considerable evidence that the nervous system and the endocrine glands are very susceptible to the effects of malarial infection and of the latter glands the suprarenals seem the most vulnerable.

Post-mortem evidence shows that these glands may be very markedly involved both in acute and chronic malaria. Although no pathological work seems to have been done on the sympathetic system in malaria, many of the clinical manifestations suggest that this system may be distinctly affected in the acute disease and the symptoms of malarial cachexia resemble those of a sympathetic-adrenal exhaustion (Anderson, 1927). Anderson (1927) points out in this connection that the first part of the malarial paroxysm resembles very closely the effects of sympathetic irritation and hyper-adrenalism.

The rise in blood pressure which occurs during the shivering stage and the fall during the hot stage suggest that the adrenal glands are actively secreting during the former stage and that their activity is diminished during the latter.

If this is occurring, one would expect a rise in blood sugar before and during the early stages of the paroxysm with a fall later. The extent of the rise would depend on the previous condition of the glands and the amount of glycogen available in the liver. In old malarial cases with relapses at frequent intervals the glycogen content of the liver would probably be low and the adrenals exhausted, so the rise would probably be smaller and of shorter duration, while in persons early in fresh infections and in relapses after a prolonged interval these organs would be but little exhausted, so the rise might be greater and its duration prolonged. This is in agreement with the results reported by Massa (1918).

The direct action of the malarial parasites on the adrenal glands may be similar to those suggested in the case of the liver cells and this may cause an increased output of adrenalin, if the effect is not too severe and the organs have not been exhausted by previous attacks of the disease.

Apart from any direct action of the parasites upon the adrenal glands, these may be stimulated through the sympathetic nervous system. Several workers have pointed out the close resemblance between the malarial paroxysm and protein shock (*vide* Sinton, 1923; Sinton, Orr and Ahmad, 1928). Nolf (1919) says that in protein shock there was a state of great excitability of certain nerves and ganglia of the autonomic nervous system, so it seems very likely that similar state of affairs may occur during the malarial paroxysm. Stimulation of this system would act on the adrenal glands causing an increased production of adrenalin and so a rise in blood sugar. That such a stimulation probably occurs in protein shock is shown by the fact that Tournade and Hermann (1928) and La Barre (1928) found an increased output of adrenalin under these conditions.

The results recorded by Rudolf and Marsh (1927) may have been due to a delayed response of an autonomic nervous system already damaged in general paralysis of the insane.

The findings reported above suggest that the adrenal glands, either directly or indirectly through the sympathetic nervous system, play an important part in the production of the rise in blood-sugar level seen in the malarial paroxysm.

(*e*) *Rise in blood sugar due to a combination of several factors.*

Of the factors which have been discussed as having a possible influence in the causation of the rise of blood sugar during the malarial paroxysm, neither an excessive intake of carbohydrates, a defective storage capacity of the liver for carbohydrates, nor a defective utilization of blood sugar by the tissues seem to have much effect. The blood-sugar changes seem to depend mainly upon an increased glycogenolysis.

Among the possible causes of the glycogenolysis, the increased metabolism of fever does not appear to have much influence. While damage of the liver

cells is probably a contributory factor, the main cause of the glycogenolysis seems to be due to an excessive output of adrenalin, caused either directly by action on the adrenal glands or indirectly through stimulation of the sympathetic system.

Protein shock as a cause of the increase in blood sugar.

Many workers are convinced that the malarial paroxysm is an 'anaphylactoid' phenomenon of the nature of protein shock. The evidence in support of this view has been summarized by Sinton (1923) and Sinton, Orr and Ahmad (1928). It is, therefore, of interest to compare the mechanism of the changes produced by such shock on blood sugar with that occurring in the malarial paroxysm.

An increase in the blood sugar has been recorded by Kuriyama (1917), by Achard and Feuillie (1922) and by Garofeano and Dérévici (1924) during peptone and seric shock.

There are several factors in the probable causation of this 'anaphylactoid' rise in the blood sugar which may also be present in the malarial paroxysm and which suggest that the two phenomena are identical.

(*a*) Hepatic engorgement occurs in malaria and Brandes and Simonds (1928) have shown that this condition in peptone shock gives rise to glycogenolysis.

(*b*) Tournade and Hermann (1928) and La Barre (1928) have found that a few minutes after the injection of peptone into animals the amount of adrenalin in the blood rises. The blood-pressure changes and the manifestations of the 'cold stage' of the malarial paroxysm suggest strongly that a similar rise in adrenalin occurs in malaria at the time of the paroxysm. Such a rise would tend to produce glycogenolysis and an increase in blood sugar.

(*c*) In peptone shock there is a diminished alkali reserve. Langfeldt (1920) and Lesser (1921) report that a rise in the pH of the blood in the liver causes an increased glycogenolysis. It therefore seems probable that the lowered alkali reserve found in the malarial paroxysm (Sinton and Baily, 1924) will act in a similar way and cause changes in the blood sugar.

(*d*) A great excitability of certain nerves and ganglia of the autonomic nervous system in protein shock has been reported by Nolf (1919), and Anderson (1927) produces considerable evidence that a stimulation and irritation of this system occurs during the malarial paroxysm. This would tend to cause a rise in blood sugar.

The evidence summarized above suggests strongly that the mechanism of increased blood sugar in protein shock and in the malarial paroxysm are of a very similar nature, if not one and the same phenomenon.

Conclusions.

Under the conditions of our investigation the following conclusions were arrived at:—

(*a*) That there is a rise in the blood-sugar level during the febrile stage of chronic benign tertian malaria, when this occurs after a prolonged period of apyrexia.

(*b*) That a similar rise probably occurs in malignant tertian malaria during the febrile stage and that this is greater than in benign tertian malaria.

(*c*) That the rise is chiefly due to an increased glycogenolysis following upon increased activity of the adrenal glands.

(*d*) That the mechanism of the glycogenolysis is very similar to, if not identical with, that occurring in protein shock.

We wish to express our thanks to Major A. E. Richmond, O.B.E., R.A.M.C., and Major P. D. Chopra, I.M.S., for the facilities which they placed at our disposal for the examination of patients.

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STUDIES ON THE ANOPHELINE FAUNA OF INDIA.

(PARTS I—IV).

BY

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[March 5, 1931.]

I. The Anopheline fauna of Kashmir.
II. The Anopheline fauna of North-West India north of latitude 30°N.
III. Varietal forms of *A. gigas* Giles and *A. lindesaii* Giles.
IV. Variation in *A. maculatus* Theo.

I. THE ANOPHELINE FAUNA OF KASHMIR.

BELOW, under the different species, is given what is believed to be a complete statement of records of Anophelines for Kashmir. These are in the main as given by Covell (1927) but classified and somewhat amplified, with the addition of further records since the time of Covell's memoir, including the result of a collection of Anophelines made by me in Kashmir in September of this year.

Kashmir in the ordinary accepted sense is Kashmir South (*see* Map accompanying Part II of this series). This includes the famous vale of Kashmir and neighbouring mountainous regions. The records in the vale chiefly relate to the neighbourhood of Srinagar and the Dal Lake, and to Tangmarg at the foot of the ghat leading from the vale to Gulmarg. The mountainous regions are represented by the Sind Valley, Harumukh and Liddar Valley areas to the north and the northern slopes of the Pir Panjal (Gulmarg) to the south. Certain records are placed here in square brackets, as for various reasons explained in the footnotes they are perhaps best excluded from among Kashmir records(1). An asterisk marks records since Covell's memoir, including those relating to the recently made collection referred to above.

The vale of Kashmir is an extensive alluvial plain (80 miles long by 30 at its greatest width) at an elevation of about 5,000 feet above sea-level. It is separated by high mountains (Pir Panjal) from the Punjab plains at a lower level, and is connected with these only by the deep gorge of the Jhelum, which

(1) The references in brackets to areas outside Kashmir are included as they have formerly been given as Kashmir localities.

runs for over 200 miles through mountains in this part of its course practically with no flat land; this isolation gives a special interest to the Anopheline fauna of the vale.

A. barianensis.

KASHMIR SOUTH : in gardens round the Dal Lake, viz., Nasim Bagh (Adie and Adie, 1913, p. 342 and ref. to this record by Gill, 1920, p. 611); Salim Bagh (Perry, 1913); *Srinagar (C. M. B. records, 1923, Sinton).

A. lindesaii.

KASHMIR SOUTH : *Gulmarg (8,500 ft.) (C. M. B. records, 1923, Sinton); *Arau (Liddar Valley, 8,000 ft), Sept. (S. R. C.); *Nara Nag (Haramukh area, 7,000 ft), Sept (S. R C.).

[CHAMBA : Makna Nullah, May-June (C M. B. records, 1914, Boyd).]

[RAWALPINDI : Kohala(2) (Gill, 1920, p. 611).]

A. gigas var. *simlensis*.(3)

KASHMIR SOUTH : Gulmarg (Gill, 1920, p. 611; *C M. B. records, 1923, Sinton); *Arau, Sept. (S. R. C); *Nara Nag, Sept (S R. C.).

[CHAMBA : Bara Nullah (C M B records, 1914, Boyd)]

A. culicifacies.

[RAWALPINDI : Kohala (Rec Punjab Mal. Bureau, quoted by Covell).]

A. listonii.

KASHMIR : [James, Mal in India, p. 32, 1902 (*A fluviatilis*).]

KASHMIR SOUTH : Tangmarg(4) (C. M. B., Gill, 1. 10. 22, adults caught).

[RAWALPINDI : Kohala (Perry, 1913; Gill, 1920, p. 611); Jhelum Road (5) (Adie, 1905, p. 5) (*A. fluviatilis*).]

A. turkhudi.

KASHMIR : (James, Mal in India, p. 50, 1902; ref. to this record by Theobald, p. 52, 1907, p. 26, 1910, Brunetti, Ann. Cat., p. 312, 1907, Christophers, Mal. in the Punjab, p. 75, James and Liston, p. 80, 1911).

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(2) Kohala is on the Jhelum River on the Kashmir frontier and the town or village is actually in Rawalpindi; the neighbourhood has little of the character of Kashmir and is much better classed with the Murree Hill area, i.e., as Rawalpindi as given above.

(3) For discussion of varietal forms *see* Part III.

(4) On road to Gulmarg at foot of hill, previously given as Tarumarg.

(5) This may be anywhere presumably on the Jhelum Road into Kashmir.

A. stephensi.

[RAWALPINDI : Kohala (Gill, 1920, p. 611).]

A. fuliginosus.

KASHMIR SOUTH : Gupkar [6] (C. M. B., 1. 10. 22, Gill, adults caught); Tangmarg (C. M. B., 1. 10. 22, Gill, adults caught); *Manasbal Lake (Jhelum below Srinagar), Sept. (S. R. C.).

[RAWALPINDI : Kohala (Gill, 1920, p. 611; Rec. Punjab Mal. Bureau, quoted by Covell).]

A. maculipalpis var. *indiensis.*

KASHMIR SOUTH : *Gundarbal (mouth of Sind Valley), Oct. (C. M. B., 1923, Mrs. Sinton).

[RAWALPINDI : Kohala (Gill, 1920, p. 611).]

A. maculatus var. *willmori.*

KASHMIR : (James, Mal. in India, p. 100, 1902 (Willmore): ref. to this record by Giles, Rev. Anop., p. 42, 1904; Blanchard, p. 624, 1905; Theobald, p. 57, 1910, Christophers, Mal. in the Punjab, p. 75, 1911; James and Liston, p. 111, 1911; Brunetti, Cat., p. 112, 1920).

KASHMIR SOUTH : streams flowing into the Dal Lake, Sept. (Gill, 1920, p. 611); Gundarbal (Perry, 1913); Sind Valley 4 miles from Gundarbal, Aug. (Adie and Adie, 1913, p. 342; ref. to this record by Gill, 1920, p. 611); *near Prang, Sind Valley, Sept. (S. R C.); *near Awantipur (Jhelum above Srinagar), Sept. (S. R. C.); *Arau (8,000 ft.), Sept. (S. R. C.); Tangmarg (C. M. B., 1914, Gill; C. M. B., 1. 10. 1922, Gill; Christophers, 1924, p. 298); Gulmarg, Aug. and Sept. (Gill, 1920, p. 611).

[RAWALPINDI : Kohala (Perry, 1913; Sept., Gill, 1920, p. 611, adults caught biting freely); Jhelum Road (Adie, 1905, p. 5) (*A. maculata*).]

The Anophelines with certainty recorded from Kashmir in a strict sense are therefore:

A. barianensis.
A. lindesaii.
A. gigas var. *simlensis.*
A. listonii.
A. fuliginosus.
A. maculipalpis var. *indiensis.*
A. maculatus var. *willmori.*

The records for *A. barianensis* relate to captures of adults in gardens near Srinagar where there are groves of fine Chenar trees (*Platanus orientalis*), in holes in which the species was probably breeding.

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(6) Previously given as Gupga.

The specimens of *A. lindesaii* from Nara Nag (7,000 ft.) were of unusual size, with a tendency to dark coloration and certain differences in the wing ornamentation from that seen in the usual type form. The question of varieties of this species is discussed in Part III.

A. gigas var. *simlensis* was extraordinarily abundant in suitable terrain at high altitudes (7,000 ft.—8,000 ft.). It was found in numbers in pools along the sides of large and small streams, very commonly under the lea of a large rock or bank. It was common in somewhat peaty pools in small streams in grassy uplands, etc. All the specimens seen have been var. *simlensis,* as distinct from var. *baileyi* occurring in eastern Himalayan areas.

The specimens of *A. fuliginosus* bred from larvæ taken in Lake Manasbal among floating weed in September had the extra dark band on the tarsus (*adiei*), but some had only a small patch of dark scales in this situation. The specimens from Tangmarg taken by Gill as adults in September were all of the normal type.

All specimens of *A. maculatus* seen from Kashmir have been var. *willmori* non-maculated form (*see* Part IV). This is in accordance with the usual distribution of forms of this species, var. *willmori* being commonly found above a certain altitude, while the Himalayan almost scaleless type form is more or less restricted to submontane areas.

All the species recorded are commonly found in the Punjab Hills, either as montane or submontane species like *A. maculatus* var. *willmori* or *A. listonii* at moderate elevations, or as alpine species, *A. lindesaii* and *A. gigas,* which are the chief species found at higher altitudes. Only the two alpine species probably extend to any great distance into the higher mountainous regions of Kashmir, as already at Nara Nag (7,000 ft.) and Arau (8,000 ft.) *A. maculatus* var. *willmori* was rare.

There is no species, except *A. fuliginosus,* recorded from Kashmir that can be described as not a hill species, and *A. fuliginosus* is so far a hill species that it occurs commonly in the larger valleys in the Punjab Hills. The Punjab plains species *A. culicifacies, A. subpictus, A. stephensi, A. barbirostris, A. hyrcanus* and *A. pulcherrimus* are unrecorded from Kashmir. The Kashmir fauna is therefore simply that of the Punjab Hill Tract, and the vale of Kashmir in spite of its alluvial character has yielded no evidence of any other fauna than that of the surrounding hill areas. There is no indication that the ordinary plains species have either colonized this large level tract, or have remained in occupation from times when, let us suppose, it might have been at a lower altitude. If such a fauna was ever present it has been eliminated (except for *A. fuliginosus*), or if there has been any importation going on, no non-hill species has established itself. This is the more striking since a characteristic of the vale is the presence of many lakes and extensive swamps which would appear to offer conditions very favourable to a rich Anopheline fauna, though the high elevation and early onset of winter has to be considered. In particular

the absence, under such circumstances, of any record of any form of *A. hyrcanus* is noteworthy.

SUMMARY.

The species recorded from Kashmir proper are: *A. barianensis*, *A. lindesaii*, *A. gigas* var. *simlensis*, *A. listonii*, *A. fuliginosus*, *A. maculipalpis* var. *indiensis* and *A. maculatus* var. *willmori*. All these species are common to the Punjab Hill Tract Anopheline fauna, to which fauna that of Kashmir belongs.

As regards the isolated alluvial plain of Kashmir, such common species of the Punjab plains as are not also hill species have either been eliminated from this area or have failed to colonize it.

II. The Anopheline fauna of North-West India north of latitude 30°N.

The receipt of a good deal of material recently from various N. W. Himalayan and trans-Indus areas, notably from the Malakand, regarding which there was previously little information available, has made it desirable to summarize what is known to date of the Anopheline fauna of that part of north-west India lying north of about latitude 30°N., or the wedge of plains and submontane country with its containing hills where the Himalayas and the ranges of Afghanistan converge to meet eventually in the region of the Khyber (Kabul River). This area (*see* Maps) embraces: the northern districts of the Punjab*, mainly consisting of plains; the hilly territories of the Simla Hills, Kangra, Chamba, Kashmir and Hazara forming the mountains and foothills of the Himalayas to the east of the Indus, which may conveniently be termed the Punjab Hill Tracts; and the trans-Indus districts of the North-West Frontier Province, which may for our purpose be divided into those lying to the north of the Kabul River, i.e., in the main the Malakand, and those south of this river, viz., Kohat, Bannu, etc., with the adjoining districts of British Baluchistan.

In the accompanying tabular statement are given the records for Anopheles up to date in different parts of this area. The information in the statement shown by crosses is that given by Covell (1927) where details regarding the exact localities, etc., will be found. Where additional information regarding districts not given by Covell has since become available this is indicated in the table by figures, the localities relating to these being given below the statement in the form of footnotes.

The species in the statement have been arranged in groups corresponding to their faunal affinities. Those classed as Mediterranean are all species well known in the Mediterranean area, e.g., in Palestine, Egypt, etc., and are definitely non-Oriental. Those classed as Oriental have a wide distribution

* For the sake of completeness records have been given relating to all those districts of the Punjab north of the southern boundary of this Province except to the east where the districts of Hissar, Karnal, Rohtak, Gurgaon and Delhi, with the Indian State of Patiala. have been omitted.

throughout a great part of the Oriental Zoogeographical Region,* occurring not only in India, but in Malay, Dutch East Indies, China, etc. Species termed Western Oriental are those having a distribution that appears to be distinct from that of the ordinary Oriental forms, in that whilst having a wide distribution in the Indian Sub-region they extend only to a limited extent, if at all, further eastwards. Such species are usually not restricted, as are the Oriental species, by the western boundary of India, but are found also considerably further westwards, e.g., in Turkestan, Mesopotamia, Arabia, etc., according to the species. They appear to be of Mediterranean general type rather than Oriental in the strict sense. *A. pulcherrimus* might have been placed as Mediterranean, but in the present connection it was thought better to consider all forms having a wide distribution in India as Western Oriental or Indian.

Reference list to locality numbers given in the statement.

(1) 39-30, May, Rawalpindi; (2) 19-26, Sept., Mari Indus; (3) 3-28, Jan., Mari Indus; (4) 13-28, April, Lahore; (5) 54-29, June, Bakloh; (6) 82-29, 123-29, July, Aug., Bakloh; (7) 66-29, June, Bakloh; (8) 62-28, 65-28, 31-29, May, June, Bakloh; (9) numerous records, May to Oct., Bakloh; (10) 76-29, July, Chakdara or Malakand†; (11) numerous records, June to Aug., Chakdara and Malakand. 1929-30; (12) in collection, received 295-30, Oct., Chakdara; (13) a number of records, June, Sept., Nov., 1929-30, Chakdara, 55-29, June, Malakand; (14) numerous records, June to Nov., 1929-30, Chakdara and Malakand. *A. willmori* from Malakand only, *A. fuliginosus* mainly from Malakand; (15) 81-29, July, Chakdara, 76-29, 235-30, 242-30, July, Sept., Malakand; (16) a number of records, July, Sept., Nov., 1930, Malakand and Chakdara; (17) 35-30, 64-30, April, June, Malakand; (18) 49-XIII-26, Oct., Nowshera; (19) 65-27, 141-29, Aug., Nowshera; (20) 49-XIII-26, 33-30, Oct., April, Nowshera; (21) 67-XIII-26, Dec., Nowshera; (22) 33-27, 141-29, 33-30, June, Aug., April, Nowshera; (23) 142-29, Aug., Jamrud; (24) a number of records, Aug. to Dec., Landi Kotal, Dargai; (25) a number of records, June to Sept., Landi Kotal, Dargai, Jamrud; (26) numerous records, July to Dec., 1928-30, Landi Kotal, Dargai, Jamrud; (27) 128-29, 76-30, Aug., June, Dargai; 180-30, 272-30, Aug , Oct., Landi Kotal; (28) 204-29, Nov., Jamrud; (29) 20-29, April, Peshawar; (30) 8-27, May, Peshawar; (31) 225-30, Sept., Chitral; (32) 22-27, 27-27, May, June, Kohat; (33) 202-30, Aug., Kohat; (34) 50-30, 72-30, May, June, Kohat; (35) 224-28, 5-30, Dec., Jan., Kohat; (36) 54-26, Nov., Damdil; (37) 50-26, Oct., Damdil; (38) 116-29, 95-30, Aug., July, Idak, Razmak; (39) 124-29, Aug., Idak; (40) Dr. Puri, Jandola, May 1928; (41) 164-28, Sept., Fort Sandeman; (42) 169-29, 96-30, Sept., July, Fort Sandeman; (43) a number of records, Sept., Oct., Dec., 1928-30, Fort Sandeman; (44) 125-30, 152-30, July, Aug., Fort Sandeman; (45) a number of records, June, July, Sept., Dec., 1929-30,

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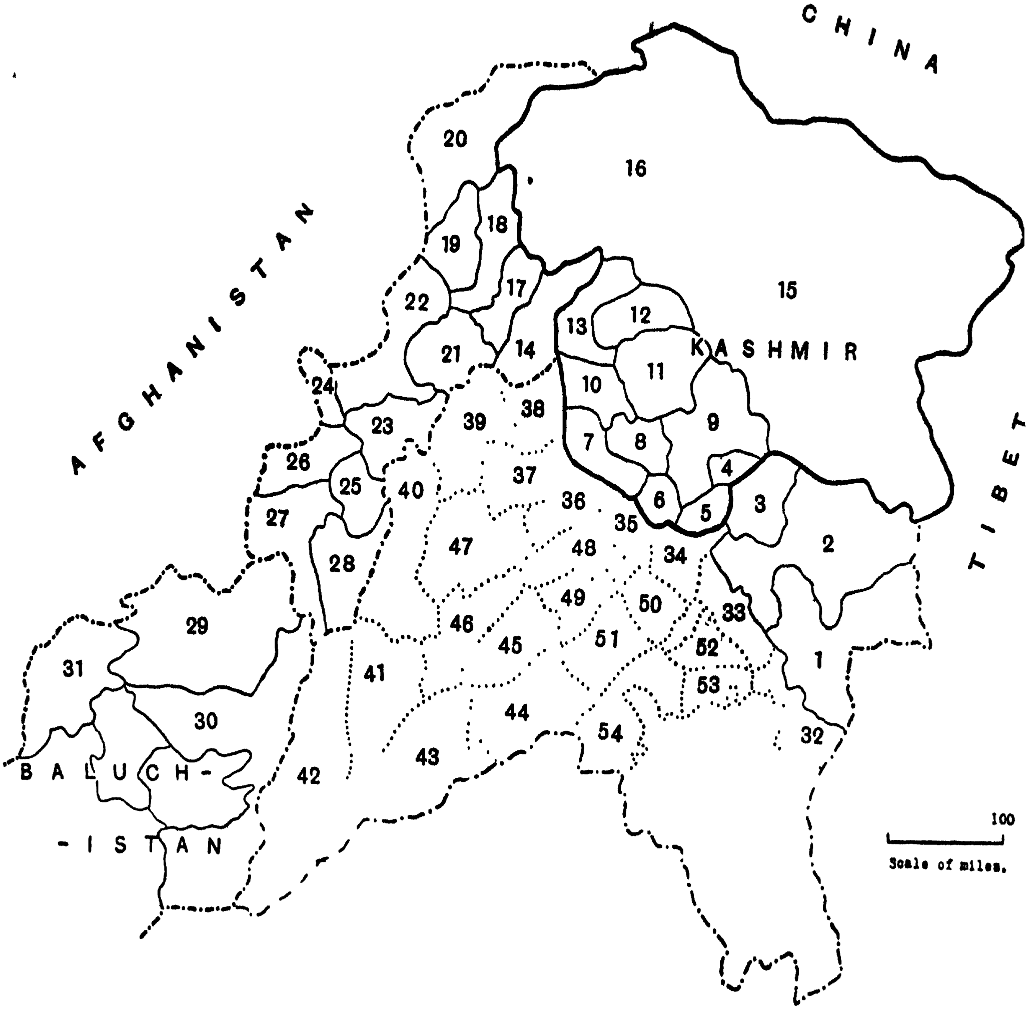
* In some cases the species is restricted to India but is very closely related to some widespread Oriental species, e.g., *A. theobaldi* which is so closely related to *A. maculatus* as to be clearly of Oriental type.

† These localities are within a few miles of each other. A single specimen unconfirmed.

Map 1.



Kashmir and a portion of North-West India showing districts.

KEY TO DISTRICTS SHOWN IN MAP.

1. Simla Hills.	15. Ladakh.	29. Zhob.	43. Multan.
2 Kangra.	16. Gilgit.	30. Loralai.	44. Montgomery.
3. Chamba.	17. Buner.	31. Quetta-Peshin.	45. Lyallpur.
4. Bhadar.	18. Swat.	32. Ambala.	46. Jhang.
5. Kathua.	19. Dir.	33. Hoshiarpur.	47. Shahpur.
6. Jammu.	20. Chitral.	34. Gurdaspur.	48. Gujranwala.
7. Mirpur.	21. Peshawar.	35. Sialkot.	49. Shekhupura.
8. Riasi.	22. Tribal Territory.	36. Gujrat.	50. Amritsar.
9. Udharmpur.	23. Kohat.	37. Jhelum.	51. Lahore.
10. Punch.	24. Kurram.	38. Rawalpindi.	52. Jullundur.
13. Muzuffarabad.	25. Bannu.	39. Attock.	53. Ludhiana.
11. Kashmir South.	26. North Waziristan.	40. Mianwali.	54. Ferozepore
12. Kashmir North.	27. South Waziristan.	41. Muzaffargahr.	
14. Hazara	28. Dera Ismail Khan.	42. Dera Ghazi Khan.	

Tract.		Ref. No. on Map.	District.	Mediterranean.				Western Oriental.						Oriental.									Alpine Oriental.		
				A. sergentii.	*A. multicolor.*	*A. dithali.*	*A. superpictus.*	*A. pulcherrimus.*	*A. turkhudi.*	*A. moghulensis.*	*A. culicifacies.*	*A. listonii.*	*A. stephensi.*	*A. hyrcanus* var. *nigerrimus.*	*A. barbirostris.*	*A. subpictus.*	*A. fuliginosus.*	*A. maculipalpis.*	*A. maculatus.*	*A. maculatus* var. *willmori.*	*A. pallidus.*	*A. theobaldi.*	*A. gigas* var. *simlensis.*	*A. lindesaii.*	*A. barianensis.*
Punjab plains.	Sub-Himalayan.	32	Ambala (*a*) ..	..	..	..	..	..	+	..	+	+	+	..	..	+	+	+	+	+	..	..	..	..	..
		33	Hoshiapur (*b*) ..	..	..	..	..	+	..	..	+	+	+	..	..	+	+	+	..	..	..	..	..	..	..
		34	Gurdaspur ..	..	..	..	..	..	+	..	+	+	+	..	..	+	+	+	+	+	..	..	..	+	..
		35	Sialkot ..	..	..	..	..	+	+	..	+	..	+	..	..	+	+	+	..	..	..	..	..	..	..
		36	Gujrat ..	..	..	..	..	+	+	..	+	+	+	..	..	+	+	..	..	..	..	..	..	..	..
		37	Jhelum ..	..	..	..	..	..	..	..	+	+	+	..	..	+	+	+	..	..	..	..	..	..	..
		38	Rawalpindi (*c*) ..	..	..	..	..	+	+	..	+	+	+	..	..	+	+	1	+	+	..	..	+	+	+
		39	Attock ..	..	..	..	..	..	..	..	..	..	+	..	..	+	+	..	..	..	..	..	..	..	..
	Indus.	40	Mianwali ..	..	..	..	..	..	..	..	+	+	+	2	..	3	+	..	..	..	..	..	..	..	..
		41	Muzaffargahr ..	..	..	..	..	+	..	..	+	+	+	..	..	+	+	..	..	..	..	..	..	..	..
		42	Dera Ghazi Khan	..	..	..	..	+	..	..	+	..	+	+	..	..	..	..	..	..	..	..	..	..	..

Central.	43	Multan	..	..	..	..	+	..	..	51	..	+	52	..	+	..	..	..	..	..	..	..	..	..
	44	Montgomery	..	..	..	..	+	..	..	+	+	+	..	..	+	+	..	..	..	..	..	..	..	..
	45	Lyallpur (*d*)	..	..	..	..	+	..	..	+	+	..	..	..	+	..	..	..	..	..	..	..	..	..
	48	Gujranwala	..	..	..	..	+	..	..	+	..	+	+	..	+	+	+	..	..	+	..	..	..	..
	50	Amritsar	..	..	..	..	+	+	..	+	+	+	+	+	+	+	+	..	..	+	..	..	..	..
	51	Lahore (*e*)	..	..	..	..	+	+	..	+	+	+	+	+	+	+	..	+	+	..	+	..	..	..
	54	Ferozepore	..	..	..	..	..	+	..	+	..	+	+	+	+	+	+	..	..	..	..	..	..	..
Punjab Hills.	1	Simla Hills	..	..	..	.	..	+	+	+	+	..	..	..	..	..	..	..	..	..	..	+	+	+
	2	Kangra	..	..	..	..	..	+	..	+	+	+	+	..	+	+	+	+	+	..	..	+	+	+
	3	Chamba	..	..	..	..	..	5	..	6	7	+	..	..	..	..	8	..	9	..	..	+	+	..
	11	Kashmir	..	.	..	..	..	..	..	..	+	..	..	..	..	+	+	..	+	..	..	+	+	+
	14	Hazara	..	..	..	..	..	+	..	+	+	+	..	..	+	+	+	+	+	..	..	+	..	..
Trans-Indus (north).	18	Swat ..	..	..	..	10	..	11	12	13	14	14	..	..	15	14	14	16	14	..	..	..	17	..
	20	Chitral	..	..	..	..	..	..	..	..	..	..	..	..	..	31	+	..	+	..	..	..	..	..
	21	Peshawar (north)	..	..	..	..	18	19	..	+	+	+	18	..	+	+	20	21	22	..	..	..	..	..

(*a*) Including Ludhiana. Records relating to Kasauli and neighbourhood are given under Simla Hills.

(*b*) Including Jullundur and Kapurthala for which there are few records.

(*c*) Records of alpine species relate to the hill station of Murree.

(*d*) Including Jhang and Shahpur for which there are few records.

(*e*) A further record for *A. theobaldi* is given under No. 4 in the reference list to locality numbers.

Tract.	Ref. No. on Map.	District.	Mediterranean.				Western Oriental.						Oriental.										Alpine Oriental.		
			A. sergentii.	*A. multicolor.*	*A. dthali.*	*A. superpictus.*	*A. pulcherrimus.*	*A. turkhudi.*	*A. moghulensis.*	*A. culicifacies.*	*A. listonii.*	*A. stephensi.*	*A. hyrcanus* var. *nigerrimus.*	*A. barbirostris.*	*A. subpictus.*	*A. fuliginosus.*	*A. maculipalpis.*	*A. maculatus.*	*A. maculatus* var. *willmori.*	*A. pallidus.*	*A. theobaldi.*	*A. gigas* var. *simlensis.*	*A. lindesaii.*	*A. barianensis.*
Trans-Indus (south).	22	Tribal Territory ..	..	..	..	+	23	24	..	+	25	+	..	..	26	27	+	..	+	..	..	..	38	..
	21	Peshawar (south) ..	..	..	..	+	+	+	..	+	+	+	29	..	+	+	+	..	30	..	..	..	53	..
	23	Kohat ..	..	..	+	+	+	+	32	+	+	+	33	..	+	+	+	34	+	..	..	..	35	..
	24	Kurram ..	..	..	..	+	..	+	..	+	+	+	..	..	..	+	+	..	+	..	..	..	..	..
	25	Bannu ..	..	..	+	+	+	+	..	+	+	+	..	..	+	..	+	..	36	..	..	..	37	..
	26	North Waziristan ..	..	..	+	+	..	+	..	+	+	+	..	..	+	38	39	..	+	..	..	..	..	..
	27	South Waziristan ..	40	+	+	+	..	+	..	+	..	+	..	..	..	..	40	..	..	..	..	..	..	..
	28	Dera Ismail Khan	..	+	+	+	+	+	..	+	+	+	..	..	+	+	..	..	+	..	..	..	..	..
Baluchistan.	29	Zhob	..	41	42	43	44	45	..	+	46	+	..	..	47	..	48	..	..	..	..	..	..	..
	29	Loralai ..	..	..	..	..	..	..	..	49	..	49	..	..	50	..	..	..	..	..	..	..	49	..
	29	Quetta-Peshin ..	..	+	+	+	+	+	+	+	+	+	..	..	+	..	..	..	..	..	..	..	+	..
	29	Persian Frontier ..	..	+	..	..	+	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Fort Sandeman; (46) 118-29, 241-30, Aug., Sept., Fort Sandeman; (47) 164-28, 70-29, Sept., June, Fort Sandeman; (48) 96-30, July, Fort Sandeman; (39) 146-29, Aug., Loralai; (50) 159-29, Sept., Loralai; (51) numerous records, May to Sept., 1928-30, Multan; (52) 169-28, Sept., Multan; (53) 374-30, Nov., Risalpur.

The Punjab Hill Tract fauna, including that of Kashmir, is clearly quite definitely in large part Oriental in character. It consists of an Oriental montane element, e.g., the species *A. maculatus*, etc., and the alpine element represented by the species *A. lindesaii* and *A. gigas*, which must be considered Oriental since these species occur in a number of areas where alpine conditions prevail distributed through the Oriental Region. There is in addition a Western Oriental or Indian component, e.g., *A. listonii, A. turkhudi* and *A. moghulensis*, which is mainly of submontane character. The 'plains' Oriental fauna does not penetrate deeply into the hill regions as is shown by observations in Kashmir, though some of the species are found in the valleys and even at considerable altitudes at no great distance from the plains. The only species in the Punjab hill fauna of which the Oriental or Western Oriental character is doubtful is *A. barianensis*. This species, however, though related to the Palæarctic *A. plumbeus* is evidently quite distinct.

From the records relating to the stations of Malakand and Chakdara and such information as is available regarding Drosh in the Chitral, it would appear that the Anopheline fauna of the Malakand (i.e., that portion of the N. W. F. Province west of the Indus and north of the Kabul River and composed of the districts Buner, Dir, Swat and Chitral) continues the Punjab Hill Tract fauna at least as far west as the Hindu Kush. Up to the present out of the large amount of material sent in the only indication from this region of any Mediterranean element has been the record (item 10 in the statement) of a single female specimen of *A. superpictus* which has unfortunately not been preserved. Here, as in the Punjab Hill Tract, and as a matter of fact throughout the whole area in review, the Western Oriental species are well represented.

The trans-Indus tract south of the Kabul River similarly shows Oriental montane species and also Western Oriental forms. But it shows also a character so far not evidenced in the tracts north of the Kabul River, viz., the occurrence of Mediterranean species. These are most numerously represented in the south (Quetta and South Waziristan) and the number of species recorded decreases as the Peshawar district is approached. There is even a distinct difference, so far as present records go, between that part of the Peshawar district south of the Kabul River (given as Peshawar, south, in the statement) and that north of the Kabul River (Peshawar, north). Of interest in this connection is material from Fort Sandeman in the Zhob district of Baluchistan showing a marked dominance of Mediterranean species. The same condition holds good at Quetta (Quetta-Pishin district of Baluchistan) where *A. superpictus* appears to be the commonest Anopheline.

Though considerable in number, the Oriental species in the plains fauna of the Punjab are nevertheless a greatly impoverished representation of the full

Oriental Anopheline fauna occurring further east, and show a reduction even of the number of Oriental species occurring in the Indian Sub-region. This impoverishment is well indicated by the entire absence of records from this area of a considerable number of common Indian species, and by the paucity of records for the species *A. pallidus* and *A. theobaldi,* both of which only just escape exclusion. The same applies in a lesser degree to the species *A. barbirostris* and *A. hyrcanus* var. *nigerrimus,* both of which it will be seen from the statement show a failing distribution even before they reach the barriers of the Afghanistan Hills and Himalayas. The remaining Oriental species of the plains, *A. subpictus* and *A. fuliginosus,* are recorded throughout the trans-Indus districts, but not further west, the Suleiman Range and the Western Himalayas being apparently a kind of rampart against which the already greatly diminished sea of Oriental forms finally breaks.

The general distribution of the faunas referred to is shown in Map 2.

Acknowledgements.

The additional information given here, as well as much of Covell's original data, is almost entirely from material sent in for identification to the Central Malaria Bureau by Officers in charge of Military and other hospitals at different stations in the area, without which our knowledge of the Anopheline distribution would have been very meagre. Capt. M. P. Conroy, I.M.S., the present medical officer in charge, Malakand and Chakdara, has not only sent a large amount of pinned material, but at Mr. P. J. Barraud's request a number of consignments of living mosquitoes put up in the method designed by this author. In using the material at my disposal I wish to acknowledge the many facilities given to me by Lieut.-Col. J. A. Sinton, I.M.S., Director, Malaria Survey of India, and the use of the work of Mr. Barraud and other members of the Malaria Survey who have received and identified this material and kept records. These records are now carefully maintained with a serial number, given first, and the year, following in abbreviated form after a stroke, and as in this form records can be referred to and verified at any time I have, except where the number is large, quoted such reference numbers in support of my entries to facilitate check and further study.

Summary.

1. The Punjab Hill Tract fauna is montane and alpine Oriental in character. It extends without admixture with Mediterranean forms across the Indus north of the Kabul River to the Malakand (Hindu Kush). It also extends to the south of the Kabul River, but there is here a rapidly increasing admixture southwards of Mediterranean species (*A. superpictus, A. dthali, A. multicolor* and *A. sergentii*), until in Baluchistan these are predominant.

2. The Oriental element in the 'plains' fauna of this area is already greatly impoverished, as compared with the much larger list of species encountered further east, even in the Indian Sub-region. But the species *A. subpictus*

and *A. fuliginosus* extend up to the Suleiman Range and Himalayas, beyond which, however, they are unrecorded.

3. The Western Oriental or Indian element, represented by the species *A. turkhudi*, *A. moghulensis*, *A. listonii*, *A. culicifacies* and *A. stephensi*, is dominant throughout the whole area, except where alpine conditions prevail, and these species as a rule continue their distribution westwards beyond the mountain barriers to Turkestan, Mesopotamia, Arabia, etc., according to the species.

III. Varietal forms of *A. gigas* Giles and *A. lindesaii* Giles.

The following summary of information regarding varietal forms of *A. gigas* Giles and *A. lindesaii* Giles based on the examination of material and the literature may be helpful.

A. gigas.

The distinguishing characters of the varieties of *A. gigas* recognized up to date are given in the form of a statement, from which more complete information can be obtained than from the usual synoptic arrangement. A space left blank means that the variety does not possess this character; where information is lacking or uncertain a query is entered. Where sometimes one condition and sometimes another exists a plus and minus sign is given. The characters given first are those which appear to be most reliable and useful in identification.

An ordinary synoptic table may, however, be found useful in addition and is given below:

A. gigas.

1.	Sixth vein with a pale spot in outer half, mid femur without a large pale spot on dorsum near apex ..	3
	Sixth vein all dark; mid femur with a large pale spot on dorsum approaching in length ⅛ of the femur ..	4
2.	Fringe spots present at 3, 4·1, 4·2 and 5·1 ..	Type form.
	Fringe without spots at these veins	2
3.	Apex of female palps more or less pale ..	*refutans.*
	Apex of female palps not so*	*formosus.* Sumatra form.
4.	Fringe dark opposite vein 3 in female† and without pale interruption from here to usual spot at 5-6	*baileyi.*
	Fringe with pale spot at 3 and usually at 4·1, if not also at other vein terminations	*simlensis.*

A. edwardsi Yamada from Japan, though somewhat resembling *A. gigas*, is quite a distinct species as noted by Edwards (Riv. di Malariol. 5, p. 273,

* This requires verification.

† The male of var. *simlensis* may show this condition.

A Gagir

Variety.	Sixth vein with a pale spot on apical half.	Inner accessory spot on costa extending to extreme base—usually longer than outer accessory spot.	Mid-femur with large pale spot on dorsum towards apex, approaching in length 8 femur.	Fringe dark opposite vein 3 in the female and without pale interruption from here to the usual fringe spot at 5–6.*	Fringe pale at 3 and 4·1 only.	Fringe pale at 3, 4·1, 4·2 and 5·1.	Apex of female palps more or less pale.	Banding of female palpi more distinct and whiter.	Outer pre-apical dark spot on costa with greater tendency to be distinct.	White rings at base of mid and hind femur broader and more conspicuous—twice diameter of femur and milky white.	Country or area.
Type form	+	+	..	..	..	..	..	..	..	..	South India.
var. *refutans* ..	+	+	..	+	..	..	+	..	..	..	Ceylon.
Sumatra form ..	+	+	..	+	..	..	..	+	..	?	Sumatra.
var. *formosus* ..	+	+	..	+	..	..	?	..	..	..	Formosa.
var. *simlensis*, form (*a*)	..	..	+	..	+	..	..	+	+	+	Western Himalayas.
var. *simlensis*, form (*b*)	..	..	+	..	..	+	..	+	+	+	Ditto.
var. *baileyi*	..	..	+	+	..	..	..	..	±	+	Eastern Himalayas, Assam, Burma, Tibet and West China.

* The male of var. *simlensis* not infrequently shows this condition.

1926). It differs from *A. gigas* in having three spots on the sixth vein, scales on the venter of segment 7 in the female, a fringe spot at 5·2 and the erect scales on the sides of the anterior promontory of the thorax light brown (not black as in *A. gigas*). The palpi are unbanded.

The four southern forms appear more closely related to each other than to the northern forms, which also resemble each other more than they do the southern forms.

Examination of material from east and west localities in Northern India appears to show that *A. gigas* from the eastern Himalayas, Assam and Burma, as well as from China and Tibet as given by Edwards (1929), is invariably var. *baileyi*. The distinction given by Edwards that this form has the two costal spots more or less fused does not seem to hold good in a great many cases, nearly as many showing discrete as fused spots. This applies not only to specimens from India but also to the very large specimens from Yatung, Tibet, in the Bureau collection. Var. *baileyi* is in fact not very different to var. *simlensis*, but appears distinct on the fringe character. In var. *baileyi* the fringe is not only dark, but is entirely so (excepting of course the usual spot at 5-6), i.e., the fringe is continuously dark from 3 inclusive onwards giving a completely unbroken band from where the pale apical area ends at 2·2 to the spot at 5-6. In var. *simlensis* there are two forms (*a*) and (*b*) more or less equally encountered in areas in the north-west and regarding which at present it cannot be said that they possess any geographical significance apart from the variety. In (*a*) the fringe spots are as previously given by me (1924) for var. *simlensis*, i.e., fewer in number than in the type or Nilgiri form. This form somewhat closely approximates to var. *baileyi* and many males show a condition of the fringe which is indistinguishable from that in var. *baileyi*. But in the female the fringe has always a pale spot at vein 3 and usually at 4·1, so that there is at least one interruption to the continuous dark fringe—there are not always 2 since the pale area at 3 is sometimes merged into the apical pale spot. In (*b*) form there are numerous fringe spots as in the type form, i.e., at 3 (unless included in the apical pale spot), 4·1, 4 2 and 5 1.

The following are recorded localities for var. *simlensis* and var. *baileyi* respectively. The asterisks signify specimens actually verified.

Var. *simlensis*. UNITED PROVINCES; Kalighat (Gahrwal), Banbassa, Dehra Dun, Roorkee, Bareilly (?), *Saharanpur, PUNJAB; *Mahasu (near Simla), Simla, *Kasauli, *Murree. CHAMBA; *Bakloh, *Dalhousie, *Bara Nullah. KANGRA; Manauli, Karaun, Rahla. KASHMIR; *Gulmarg, *Nara Nag, *Arau. N. W. F. PROVINCE (Hazara); *Abbottabad.

Var. *baileyi*. WESTERN CHINA. *TIBET; Yatung, Everest. UPPER BURMA; *Kalaw. ASSAM; *Shillong, Dumpep (Khasi and Jaintia hills), *Doom Dooma (400 ft.). CACHAR; *Lebac. NORTH BENGAL; *Saidpur.

A. lindesaii.

Form or variety.	Termination of wing veins.	Ornamentation of base of hind femur.	Scaling on base vein 1 (remigium).	Proportion distal pale band on femur to succeeding dark area.	White basal rings on front and mid femora.	Scaling of wing (vein 2·2).	Fringe spot 5·2 and 6.	Country or area.
Type form ..	All or either 3, 4·2, or 5·2 and frequently 2·2 and 4·1 pale; rarely 5·1	Ventral aspect pale for about $\frac{1}{3}$ length femur; dark scaling dorsally extends to, or nearly to, trochanter.	Black.	$\frac{2}{3}$	Less conspicuous.	Narrower.	±	Himalayas.
var. *pleccau* ..	Ditto.	Ditto ventrally; dark scaling dorsally leaves a broader gap (equal to about $\frac{1}{2}$ ventral pale extent).	Black.	$\frac{2}{3}$	Ditto.	Ditto.	+	Formosa.
var. *japonicus*	Ditto; but sometimes 5·1, but not 2·2, pale.	Ventral aspect pale for about $\frac{1}{4}$ length femur only; dark dorsally to trochanter.	Black.	$\frac{2}{3}$	Poorly developed or absent.	Broader.	±	Japan.
var. *nilgiricus* ..	2·2, 3, 4·1, 4·2, 5·1 and 5·2 all dark.	With conspicuous pale ring, the white not extending beyond on ventral aspect, and ring less than $\frac{2}{3}$ distal pale band.	Yellow.	$\frac{1}{2}$	Conspicuous about width of femur in extent.	Ditto.	..	South India.
var. *cameronensis*	Ditto.	With broad pale band at base, the white not extending beyond on ventral aspect, the ring about $\frac{1}{8}$ femur and $\frac{2}{3}$ distal band.	Black.	$\frac{1}{2}$	Conspicuous, as wide, or twice as wide as, femur in extent.	Ditto.	..	Federated Malay States.

A. lindesaii.

The points of distinction between the different described varieties of *A. lindesaii* are also given in tabular form.

Or the varieties may be distinguished by the use of the following synoptic table and reference made to the table for confirmation:—

A. lindesaii.

1.	Terminations of at least one vein, other than 2 1 and 6 pale	2
	Terminations of all veins, other than those mentioned, dark	4
2	Ventral aspect of femur pale for 1/3 its extent at base	3
	Ventral aspect of femur at base not above 1/6 length of femur pale	*japonicus*
3	Femur also pale dorsally at base for some distance ..	*pleccau*
	Femur with dark scaling on the dorsum extending to, or nearly to, the trochanter	*type form*
4	Remigium with dark scales; hind femur with conspicuous pale band at base equal to 2/3 breadth of distal pale band on femur	*cameronensis*
	Remigium with yellow scales; hind femur with pale band at base less than 2/3 breadth of distal pale band	*nilgiricus*

With *A. lindesaii* also the difference between the Peninsular and Himalayan forms appears to be greater than that between the different northern forms and southern forms respectively.

Var *pleccau* Koidzumi seems to differ from the type form only in a greater extent of white dorsally at the base of the hind femur*. In the type form there is usually a line of black scaling which passes up on the dorsum of the femur to, or nearly to the trochanter. In specimens from Formosa in the Kasauli collection there is a broader gap of white. If this condition is invariably present in the Formosan form *pleccau* might possibly be retained as a valid variety. Occasionally, however, specimens of the type form show a larger gap of white than usual.

The difference between var. *japonicus* and the type form is again chiefly in the amount of white at the base of the hind femur, about one-third of the femur being white ventrally at the base in the type form and according to Yamada (1925) only about 1/6 in var. *japonicus*. The somewhat broader scaling in var. *japonicus* is not very easy to use as a means of identification, nor is the slight difference in the parabasal spines. Any reliable differences

* This only refers to the small number of specimens in the Kasauli collection and requires confirmation.

in the wing markings are slight. There is considerable variation seen in the spotting of the ends of the veins in the type form. The commonest arrangement is for there to be a pale spot at the termination of veins 3, 4·2, 5·2 and 6, but any of these may be missing, though practically never all and 4·2 rarely. The remaining veins may be dark at their terminations or there may be pale spots at either or both 2 2 and 4 1. A spot at termination of 5 1 is very rare, if it occurs at all. The differences noted by Yamada, viz., the absence of a pale spot at 2 2 and presence of a pale spot at 5 1 in some cases in the Japanese form, appear therefore to hold good.

Available material from the eastern Himalayas (specimens from Sureil and Sikkim) gives no evidence of any eastern Indian form of *A. lindesaii* corresponding to var. *baileyi* in the case of *A. gigas*. Some of the Sureil specimens show an increased amount of white at the base of the femur dorsally, but the majority are much as in the type form from further west and the difference if any is too slight to stress.

The specimens from Nara Nag in Kashmir consistently show a dark termination to veins 2 2, 3 and 4 1, but there is always a well marked spot at 4 2. Here also the amount of white at the base of the femur dorsally is sometimes increased, but most specimens show a thin line of dark scales more or less approaching the trochanter. These were very large forms with well contrasted markings and the white rings at the base of the fore and mid femora conspicuous.

The southern form, var. *nilgiricus*, is at once and easily differentiated from any of the above, not only by the dark base of the femur with a white ring only as in the front and mid femora, but very sharply by the wing markings (terminations of veins 2 2, 3, 4 1, 4 2, 5 1 and 5 2 all dark) and by the yellow scaled remigium, this last being lined on either side with perfectly black scales in all the other forms. There are also other points of difference as previously mentioned and as given in the statement. The extent of pale at the base of the third vein previously given by me (1924) as a distinguishing character is, however, too variable to be relied upon. The white rings on the bases of the femora are conspicuous in this form.

Var. *cameronensis** resembles var. *nilgiricus* in the dark vein terminations and in the general ornamentation of the bases of the femora. It differs from this form in the black scaling (instead of yellow) at the base of vein 1 (remigium) and in the greater breadth of the pale rings on the bases of the femora, especially that on the hind femur which as noted by Edwards reaches 2/3 the length of the distal white band.

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* Lt.-Col. J. A. Sinton, I.M.S., has recently brought specimens of this variety to the Kasauli collection, very kindly given to him in the F. M. S. by Dr. K. B. Williamson and Dr. A. G. H. Smart. The specimens are from the Cameron Highlands, Federated Malay States. I am much indebted to Col Sinton for the opportunity to study this material.

SUMMARY.

The characters of the different varietal forms of *A. gigas* Giles and *A. lindesaii* Giles are summarized.

The form of *A. gigas* occurring in the Eastern Himalayas, Assam Hills and Burma appears invariably to be var. *baileyi* Edwards as contrasted with var. *simlensis* in the north-west.

IV. VARIATION IN *A. maculatus* THEO.

A large amount of material from various parts of India and Burma and a smaller number of specimens from China, Formosa, Philippines, Federated Malay States and Ceylon, together with some material brought recently by Col. J. A. Sinton, V.C., I.M.S., from Siam, has recently been studied by me with the object of ascertaining what significant variations, if any, occur in this species over the large area through which its distribution extends.

Palpal markings.—The female palps in *A. maculatus* occasionally shows well marked white spots (speckling) on segment 3 (counting as segment 1 the small rudimentary basal segment). This is, however, as a rule much more frequent and pronounced in var. *willmori*. In var. *willmori* from the extreme north-west (North-West Frontier Province and Kashmir) speckling does not seem to occur, or has not yet been seen. But from all areas further east a large proportion of individuals show various degrees of it. This appears a useful character in distinguishing var. *willmori* from *A. maculatus* type in the eastern areas, where the type form frequently shows relatively heavy abdominal scaling. Speckling is not common in the non-scaly Himalayan form referred to later, and if the palps are marked at all it is usually with a diffuse longitudinal tache along the dorso-inner aspect of the segment. Similarly speckling is not definitely seen according to Yamada (1925) in the Formosan form (*hanabusai*).

Mesothoracic scaling.—Yamada (1925) has given as characteristic of *A. hanabusai* from Formosa more oval and roundly terminating scales on the median area of the mesothorax. In *A. maculatus* the scaling in this situation is usually narrow and somewhat pointed, but some specimens show a much broader looking scaling. Some specimens of var. *willmori* show conspicuously broad scaling, in others it is much narrower. I have not been able to make any definitive use of this character, and doubt if it can be relied upon to distinguish any of the different forms.

Wing markings.—A most noticeable variation in the marking of the costa is the length of the pre-apical dark spot (i.e., the dark area between the median or main dark spot and the small dark costal spot towards the apex of the wing). The pre-apical dark spot may be short, about equal to or not exceeding twice the length of the pale area just external to it, or it may be much longer and up to 5 times the length of the pale area beyond. The shorter condition is the more usual in *A. maculatus* and the comparatively long spot

in var. *willmori*. But the variation in individuals is very considerable, and in *A. maculatus* from certain areas there is commonly a much longer pre-apical spot. Further, variable features occur in the extent of the subcostal and other pale areas, but these also are subject to great individual and local differences. Variations as regards the absence or presence of certain small dark areas in the wing-field occur, e.g., on the stem of vein 2, at the bases of veins 4·2 and 5·1, the small spot on vein 1 on the inner side of the main spot, etc., but appear to have no particular significance.

Dark scaling on the stem of vein 4 between the cross-veins is given by Yamada (1925) as characteristic of *A. hanabusai,* but this has been observed in specimens of *A. maculatus* from the Punjab, the Nilgiris, Bengal, Assam and Siam.

Leg markings.—In *A. maculatus* the usual condition is for the banding on the fore-tarsus, notably that at joint 2-3, to be apical plus basal and that on the mid tarsus apical only. In var. *willmori* the banding on the fore tarsus is frequently apical only, with narrow or no banding on the mid tarsus. Further, in place of actual bands var. *willmori* commonly shows white taches not extending to the back of the joint. Critical analysis has shown, however, that this banding in all forms is very liable to modification. Out of 23 var. *willmori* taken at random from different areas 7 showed some basal as well as apical banding on the fore legs, and 11 quite considerable markings on the mid tarsus.

Yamada has given certain differences in the extent of the pale markings on segments 2 and 3 of the hind tarsus. The more usual condition in *A. maculatus,* including the pilose Himalayan form and the Formosan form, as against var. *willmori,* is for segments 2 and 3 of the hind tarsus to have respectively about 1/6 and 1/4 apically pale, whereas in var. *willmori* the proportion is about 1/5 and 1/3. The extent of variability in both these forms is, however, sufficient to prevent any definitive use being made of this character. In 20 *A. maculatus* taken at random from various localities the proportion was 1/6 and 1/4 or less in 16 and about 1/5 and 1/3 in 4; in 27 var. *willmori* it was about 1/5 and 1/3 in 20 and about 1/6 and 1/4 in 7.

The dark area on the second tarsal segment of the fore and mid legs and the third on the hind leg are usually devoid of spots. But in var. *willmori,* in specimens where there is speckling of the palps, as also noted by James and Liston (1911), from one to three small white spots in one or all of these positions is common. But this condition is even commoner in the pilose Himalayan form and is present in *A. maculatus,* typical form, from some areas, e.g., Siam. Yamada also mentions spotting in this position on the fore tarsus as being present in *A. hanabusai.*

The under surface of the mid, and sometimes of the hind femur, as described by Yamada for *A. hanabusai,* is commonly pale for some distance from the base. This was very conspicuous, extending for nearly the complete length of the femur, in some of the Siam specimens, and is also rather marked in the

Formosan specimens in the Kasauli collection. Some degree of it is more or less constant, however, in specimens of *A. maculatus* from various parts of India.

Abdominal scaling.—A number of scale features are present on the abdominal segments of *A. maculatus*, each of which may be more or less developed in individual specimens or series. These are:

(1) The general scaling of the dorsal aspect of the tergites.

(2) Black scales on the lateral posterior angles of the terminal tergites, forming when well developed a condition approaching tufts, or represented by a certain number of erect black individual scales.

(3) Broad white scales on the ventral aspect of segment 8, often forming a heavily scaled area on either side of the segment.

(4) Scattered broad white scales on the ventral aspect of segments 5–7.

(5) Black scales on the ventral aspect of segments 5–7, more or less confined to the posterior part of the segment near the middle line.

The general scaling of the dorsum has received much attention in regard to the differentiation of *A. willmori* and *A. maculatus*. Study of *A. maculatus* (type form), which is the form described by me (1924) as var. *dravidicus*, confirms what I have formerly said as to this form being characterized by great individual variation in the abdominal scaling, not only in respect to the number of segments carrying scales, but also in the width of the scales. Most commonly *A. maculatus*, as seen in specimens from China, the Philippines and various parts of Peninsular India, carries a few narrow scales on the anterior segments and more numerous and broader scales on the last few segments of the abdomen. Frequently scales may be absent on segments 3 or 4 or both even when a few are present on segment 2, or scales may be present on the last two segments or so only, or even confined to the last segment. Altitude or other causes associated with certain localities appears to increase the amount and breadth of scaling in a proportion of individuals, so that besides forms showing the normal condition a varying number may show a marked degree of broader scaling which may extend to all the abdominal segments, even in some cases to segment 2, where there may even be a patch of broad scales, though as a rule this patch is not really so marked, nor is the rest of the abdomen so heavily scaled, as in specimens of var. *willmori* from the Himalayan area. As pointed out by me (1924) in a previous paper, this variation in individuals is characteristic, and may be accepted as indicating that the typical form is being dealt with.

In the Himalayan area such intermediate forms as have been referred to do not exist, or rather are very rare, and specimens are either heavily scaled on segments 3–8 with a patch of broad scales on segment 2 (var. *willmori*) or they are of the pilose form of *A. maculatus*. In this form the scales are confined to the dorsal aspect of segment 8 and even on this segment are inconspicuous being very narrow and mixed with hairs. It seems probable that what is here called the pilose form is Theobald's *pseudowillmori*, regarding

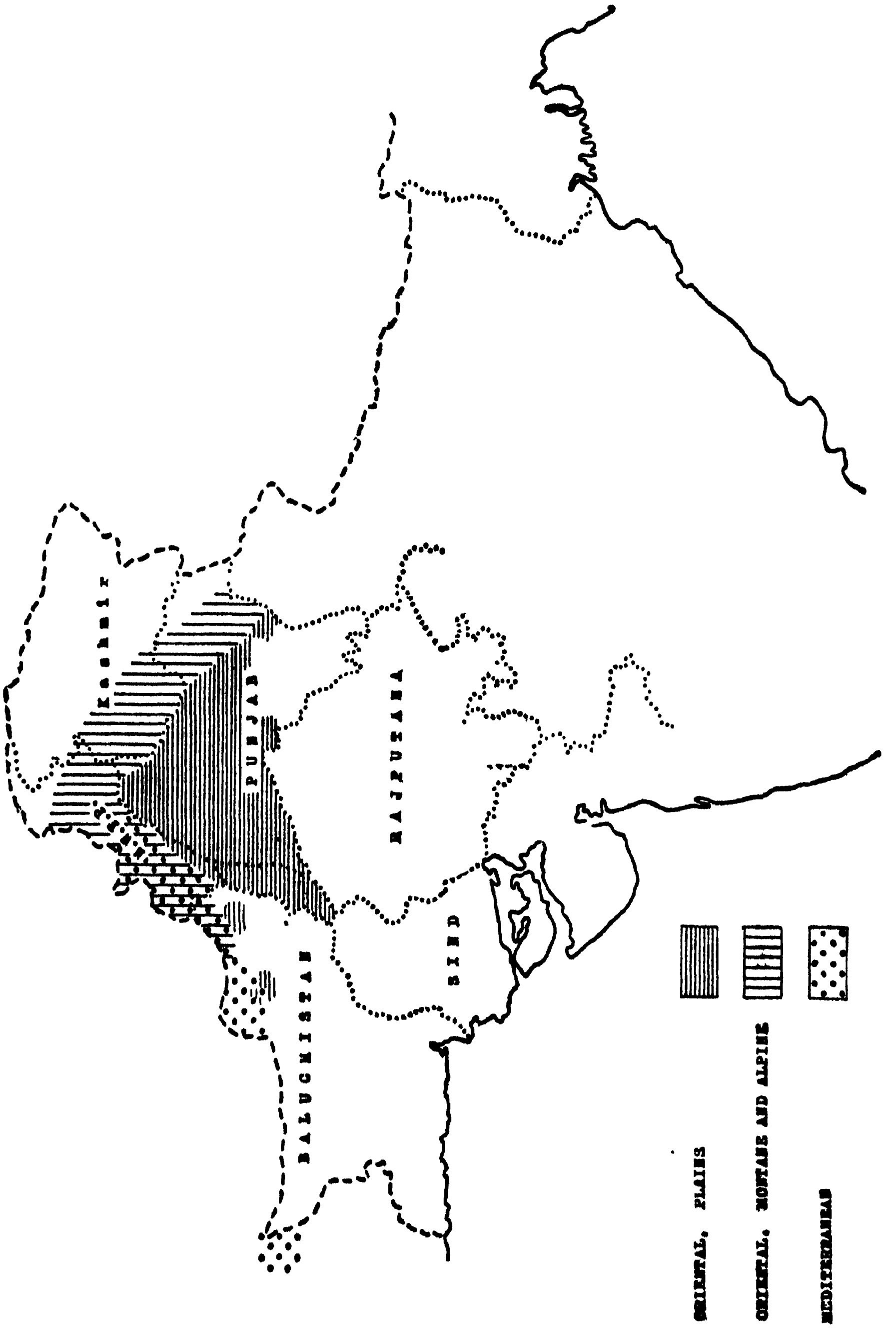
which Theobald makes the following statements 'Abdomen brown with golden hairs,' and also 'abdomen steely black with brown hairs with pale golden reflections, more gold at apex,' this latter being a very good description of the appearances seen.

In both these Himalayan forms the amount of variation is small, though in large series occasional rare exceptions are seen. Among a large number of var. *willmori* (maculose form) from Dehra Dun an example was found with maculated palps and rather scanty scales on a number of segments, and with no broad scales on segment 2. Among a series of the pilose form from the same locality were found two specimens showing scales of a broadish type on two or three segments, i.e., resembling the type form. Further in a large series from Shillong the majority of specimens were quite typical of the pilose form, but about 20 per cent, otherwise very similar in appearance, showed narrow scaling extending to two or three segments. A similar condition was seen in series from Bengal. The distribution of the two Himalayan forms is not coincident, though they may occur together in some localities as at Dehra Dun mentioned above. The pilose form is very distinctly submontane (about 2,000 ft.) whereas var. *willmori* is in a higher zone (2,000–8,000 ft.); further the pilose form does not appear to occur in Kashmir where var. *willmori* is common.

The tuft-like patches of black scales at the postero-lateral angles of the tergites are commonly present in *A. maculatus* on segments 7 and 8, and frequently on 6, or even more rarely represented by some dark scales on 5. Specimens from some areas appear to have this feature more developed than those from other areas. The scaling is notably conspicuous in specimens from the Northern Shan States and from Siam, but is also often marked in South Indian specimens, and any definitive differences would be very difficult to maintain owing to considerable individual variation even in such areas. In the non-maculated var. *willmori* from Kashmir and the N. W. F. Province, though the dorsal scaling is very heavy these tufts appear to be undeveloped except on segment 8; in the *maculosa* form further east they are commonly present also on 7, or on 6 and 7, and are often conspicuous. In the pilose Himalayan form they are entirely restricted to segment 8 and even on this segment they are feebly developed. In *A. hanabusai* these tufts appear to be a well marked feature, and are given by Yamada as on segments 6–8, or even 4–8.

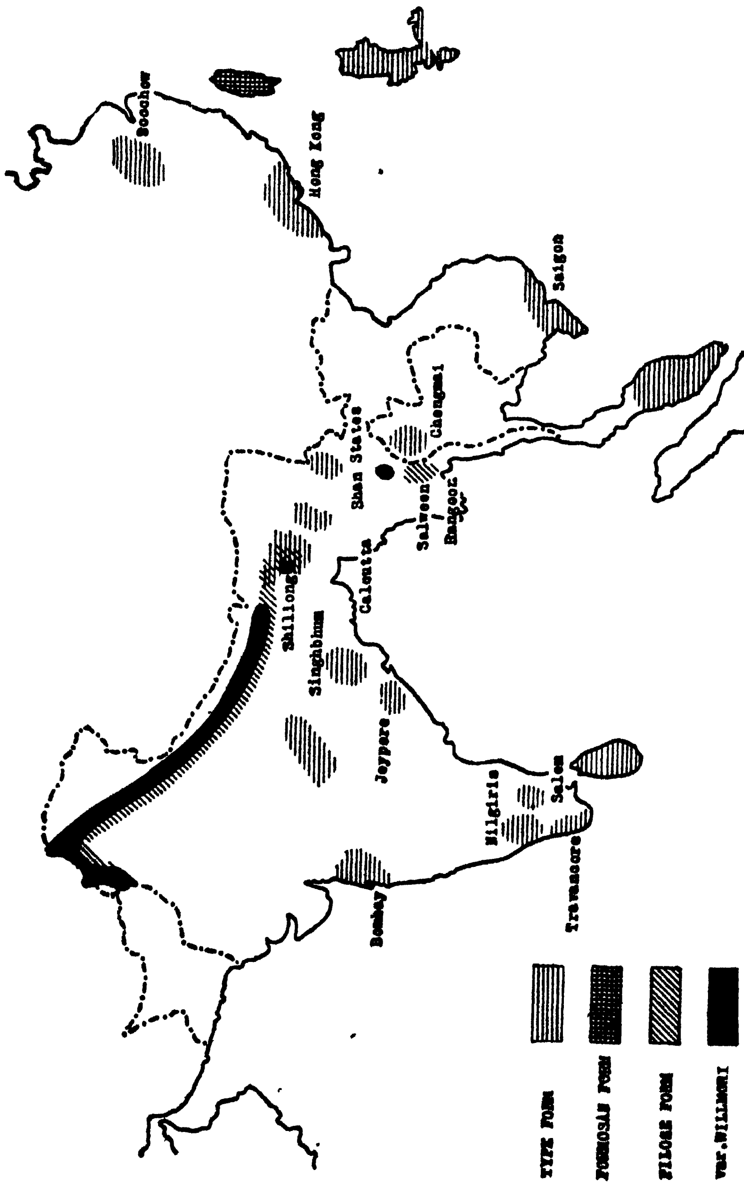
Broad white scaling on the ventral aspect of segment 8 is conspicuous in var. *willmori*, but is often present in scaly forms of the type. Narrower scales are often present, so that definition is difficult. Scattered broad white scales on the ventral aspect of segments 5–7 are very characteristic of var. *willmori* and the Formosan *A. hanabusai*, but scales of a similar kind, even if somewhat narrower, are often seen in the type form. Black scales towards the apices of the segments on their ventral aspect are commonly present on 5–7 except in the pilose form. In *A. hanabusai* they are described by Yamada as present

Map 2.



Showing situation of the area dealt and chief faunal features.

MAP 3.



Showing known distribution of forms of *A. maculatus* Theo.

also on 2–5. On the whole these scales appear to run along with the degree of development of the black lateral scaling. The black scaling appears to be very well developed in the Formosan form, but it is doubtful if definitive use could be made of the character. All these scale characters seem to be too subject to individual variation to be used at all in a definitive sense.

Taking everything into consideration the facts seem to point to there being a single species, *A. maculatus,* of which the forms *willmori* and *hanabusai* are at most varieties. I do not think it is possible on data now available to substantiate *hanabusai* as a defined variety, and for the present regard it as a perhaps rather special development of the typical type form. Even var. *willmori* is not easily defined, and would frequently be difficult to identify precisely in the absence of a series of specimens. Two forms of this variety have already been mentioned, viz., the form from the N. W. F. Province and Kashmir (type locality) where associated with some other small differences there appears to be no maculation of the palpi, and the form from further east where maculation of the palps is common, amounting practically to a differentiating character as a rule in series. It is possible that both of these are geographical varieties, and it seems quite certain that the pilose form is so. I have not employed any name, however, for any of these forms, since attempts at identification would be bound to lead to confusion, and their recognition must be regarded as mainly of importance in purely geographical and varietal studies.

The data gathered regarding the distribution of the forms mentioned are illustrated in Map 3.

The following appear to me deserving of recognition as named varieties or recognized forms of the species:—

A. maculatus Theo.

Typical form.

Syn. var. *dravidicus* Christophers, **1924.**
A. hanabusai Yamada, **1925.**

Scales present on at least the last two or three segments; the actual extent of scaling very variable, but in heavily scaled specimens only occasionally with a well marked patch of broad scales on segment 2. Black scales usually present at lateral posterior angles of at least segment 7. Female palpi only speckled in a small proportion of individuals.

Distribution.—This form has been identified by me from: Soochow, CHINA; FORMOSA; PHILIPPINES; Seramban, Linsum, Bukit Kiara, FEDERATED MALAY STATES; Chengmai, SIAM; Namtu (Northern Shan States), Mawlaik (Upper Chindwin), BURMA; Nongpoh, Lumding, Haflong, ASSAM; CACHAR; SYLHET; Meenglas (Jalpaiguri Duars), BENGAL; Duia, Chiria, Manarpur, SINGHBHUM; Koraput (Vizagapatam D.), JEYPORE HILL TRACTS; Coonoor, Mettapolium, NILGIRI HILLS;

Kurumbapatti (Salem D.), MADRAS; TRAVANCORE; Colombo, Suduganga, CEYLON; Calicut, MALABAR; Mercara, COORG; Kadur D., MYSORE; Andhra Valley, BOMBAY; Rewah State, Jubbulpore D., CENTRAL INDIA.

Pilose form.

Syn. *Nyssorhynchus pseudowillmori* Theo., 1910.

Scales confined to dorsum of segment 8, narrow, mixed with hairs and inconspicuous; black scaling at posterior angles of segments restricted to 8 and usually here poorly developed. Female palpi only speckled in a small proportion of individuals, often marked with a longitudinal flavescent tache towards inner dorsal aspect; black scales between the cross-veins on vein 4 rather commonly present.

Distribution.—This form has been identified by me from: Nowshera, Abbottabad, N. W. F. PROVINCE; Kasauli, Chandigarh, Madhopur, PUNJAB; Saharanpur, Dehra Dun, Panch Koria, Banbassa, Bhowali, UNITED PROVINCES; Rajabathakawa, Marianbari (Bengal Duars), BENGAL; Shillong, ASSAM; Papun (Salween D.), LOWER BURMA.

A. maculatus var. *willmori* James, 1903.

Syn. *Neocellia indica* Theo., 1907 (Dehra Dun).
Neocellia dudgeoni Theo., 1907 (Kangra Valley).
var. *maculosa* James and Liston, 1911 (Pathankot, Kurseong).

Segments 3-7 of abdomen with a covering of broad scales; a well developed patch of broad scales on segment 2; little or no variation in this respect in individuals. Except in north-west characterized by conspicuous speckling of the palps in a large proportion of individuals in any series.

Distribution.—This variety has been identified by me from the following localities, those marked with an asterisk being localities from which the *maculosa* form has not been seen. *Kotkai, *Kohat *Peshawar, *Nowshera, *Chakdara, *Malakand, *Abbottabad, N. W. F. PROVINCE; *Tangmarg, *Prang, *Awantipur, *Arau, KASHMIR; Bakloh, CHAMBA; KANGRA; Pathankot, Kasauli, PUNJAB; Saharanpur, Dehra Dun, Bhowali, UNITED PROVINCES; Marianbari (Bengal Terai), BENGAL; Kurseong (James), Sureil, EASTERN HIMALAYAS; Shillong, ASSAM; Kalaw (Southern Shan States), BURMA.

The question further arises whether *A. theobaldi* Giles of Central and West India is also merely a variety of *A. maculatus*. This form differs markedly in the constant tarsal character of two segments completely white. This is not merely that certain individuals show this condition among a number of more normal *A. maculatus*. That it is not a mere individual variation is shown by the fact that *A. theobaldi* is not recorded from large areas where *A. maculatus* occurs, and conversely this form is commonly sent from areas like Central India where *A. maculatus* itself is not specially common.

It is clearly very close to *A. maculatus*, but apart from the difference in tarsal markings there appear to be certain other small differences. The base of the costa is very consistently darker with a much greater tendency to fusion of the accessory spots, often leaving but little pale scaling; the dark areas on the costa are relatively longer compared with the pale interruptions; the fore tarsi are commonly apically banded only, and the under surface largely or entirely dark; the mid tarsi are dark or very narrowly banded and the under side all dark; the abdominal scaling is rather broader on the last few segments in proportion to the scaling on the anterior segments as compared with *A. maculatus*, and the scaling is possibly somewhat whiter and more transparent in appearance. No differences however have been detected in the hypopygial, pharyngeal or larval characters.

Everything considered I think it would be undesirable at present to sink this species as a variety of *A. maculatus* and it is better still to regard it as a closely related but distinct species.

Summary.

Variation shown by *A. maculatus* Theo. is described. *A. willmori* James and *A. hanabusai* Yamada can at most be regarded as varietal forms, and it is doubtful if the latter can be maintained as distinct from the type.

The following appears to be the position in regard to geographical forms of the species: (1) *A maculatus* (type), including (*a*) typical form (var. *dravidicus* Christophers and *A. hanabusai* Yamada), with a very variable degree of scaling but with scales at least on the last two or three segments, distributed through China, Philippines, Indo-China, Siam, Burma and Peninsular India and Ceylon, and (*b*) an almost scaleless form (*pseudowillmori* Theo.) with scales confined to the eighth segment, very narrow and mixed with hairs, distributed along the submontane of the Himalayas; (2) *A. maculatus* var. *willmori* James with consistently heavy abdominal scaling and towards the east with a large proportion of individuals showing maculation of the palps (var. *maculosa* James), distributed along the whole Himalayan range as a montane species at altitudes between 2,000–8,000 ft.

A. theobaldi Giles is a very closely related species but is on present evidence considered as distinct.

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A SIMPLE AND INEXPENSIVE PORTABLE SCREENER FOR USE WITH PARIS GREEN DILUENTS.

BY

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[March 31, 1931.]

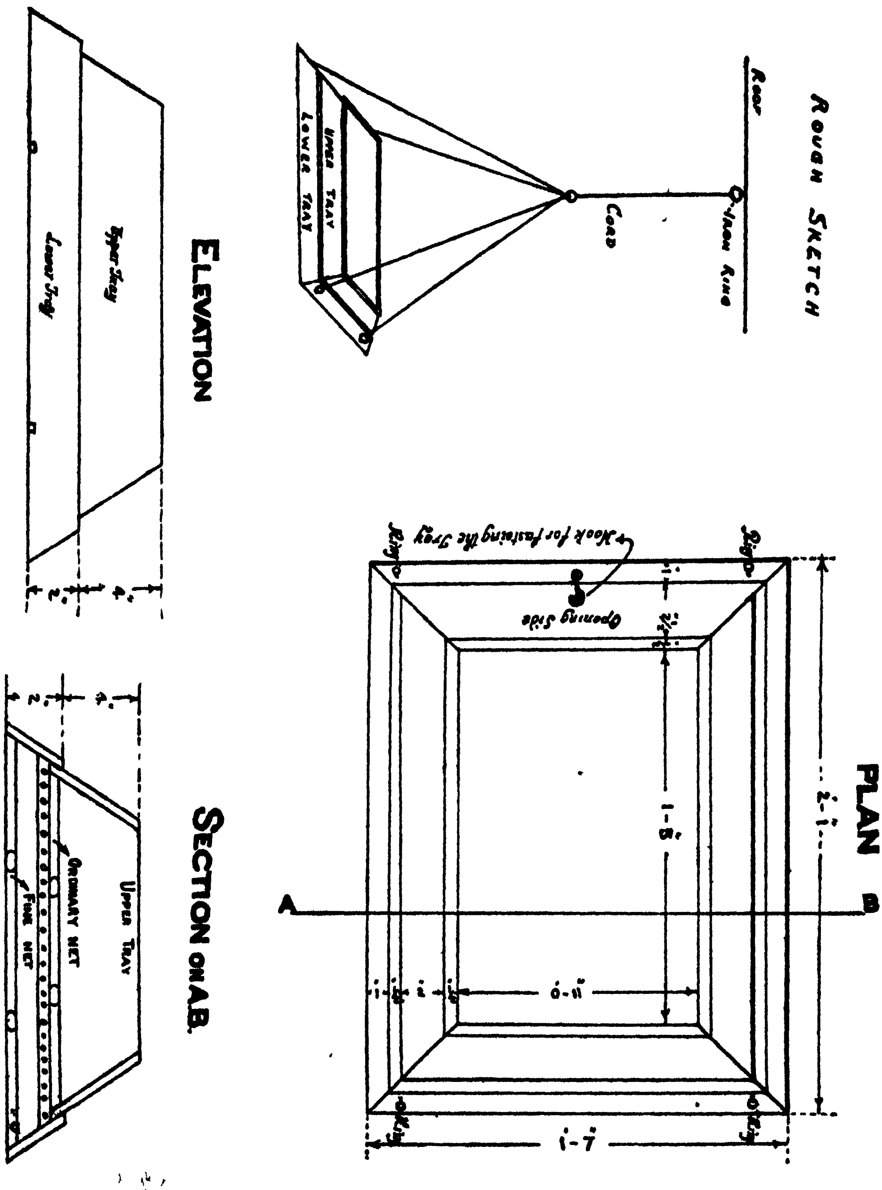
The type of screener usually employed for road dust, hydrated lime and other paris green diluents consists of a box mounted on iron legs, containing within it two concentric wire gauze cylinders which are rotated by hand. This type of apparatus has certain disadvantages. In the first place it is expensive, costing about Rs. 40 or Rs. 50; secondly, it is cumbersome and heavy for transport; and, thirdly, it has frequently been found to get out of order, especially when operated by ignorant coolies.

The screener described below has been designed to overcome these disadvantages. It is inexpensive and of simple construction, so that it can be made by any village carpenter at a cost of about Rs. 5; it is easily transported from place to place, being light and of small bulk; there are no complicated parts to get out of order; and, as it closely resembles the sieve which is in common use in Indian villages for sifting flour, the average coolie finds no difficulty in using it.

The apparatus consists of two rectangular wooden trays, fitted one above the other, the bottom of each being made of wire gauze. The upper tray is fitted with ordinary galvanized iron fly-proof gauze, mesh 12 to the linear inch; the lower with copper or brass wire gauze, mesh 40 to the linear inch. The sides of both trays slope inwards at the top, in order to prevent the dust from spilling out. Two slips of wood are fixed across the bottom of each tray to prevent the wire gauze from sagging.

The material to be screened is placed in the upper tray, and the apparatus is worked by hand with a side to side motion after the manner of sifting flour, the coarser particles being retained in the upper tray. The screener may also be suspended from a hook fixed in the roof by cords attached to rings placed at the four corners of the lower tray (*see* Text-Figure).

After each sifting the upper tray is pulled out, and the particles retained in it emptied out. It is then slid back into position and fastened with a hook



on each side. After several siftings the particles retained in the lower tray are also emptied out.

Dimensions.

		Length.		Breadth.		Depth.
Upper Tray	.. Top	1′	5″		11″	
	Bottom	1′	11″	1′	5″	4″
Lower Tray	.. Top	1′	11″	1′	5″	
	Bottom	2′	1″	1′	7″	2″
Whole Apparatus	.. Top	1′	5″		11″	
	Bottom	2′	1″	1′	7″	6″

There is a space of 1½ inches between the two pieces of gauze.

The apparatus has been used successfully during the past year in experimental work with paris green carried out in Larkana District by the Sind Malaria Inquiry and by Dr. Haji Kassim, Health Officer, District Local Board, Larkana, Sind.

I wish to thank Subedar J. D. Baily, I.M.D., Officer in Charge, Sind Malaria Inquiry, for his practical suggestions in designing the apparatus.

ERRATA.

In place of Errata Slip issued with Vol. II, No. 2, the following should be substituted :—

Page 288 line 16	for	7·8	read	0·0078
,, ,, ,, 18	,,	3·2	,,	0·0032
,, 291 ,, 1	,,	4·6	,,	0·0046
,, ,, ,, 2	,,	9·8	,,	0·0098
,, ,, ,, 3	,,	4·9	,,	0·0049
,, ,, ,, 4	,,	4·3	,,	0·0043
,, 317 ,, 30	,,	2	,,	3
,, 318 ,, heading of table	,,	Gagır	,,	gıgas
,, ,, first line of table. There should be a + in column 7 (Fringe pale at 3, 4·1, 4·2, and 5·1)				
,, 332 line 5 from below	,,	Kordzumı	,,	Koıdzumı.

Records of the Malaria Survey of India, Vol. II, No. 3, September, 1931.

NOTES ON THE INDIAN TOUR OF THE MALARIA COMMISSION OF THE LEAGUE OF NATIONS.*

BY

PROFESSOR W. SCHÜFFNER.

(President of the Indian Commission.)

SOME members representing the Malaria Commission of the League of Nations made a visit to British India, lasting from August 1929 till January 1930. These members were Doctors de Buen, Ciuca, Swellengrebel and myself. Professor Peltier (France) and Dr. Williams (U. S. A.) were co-opted under special invitations from the President of the Health Committee of the League of Nations and the President of the Malaria Commission.

The object of the tour was to enable the Commission to collect personal impressions, on the spot, of the extent and character of malaria in India, as well as of the results achieved by research and by anti-malarial operations. Since 1924 several study tours of this nature have been made by the Malaria Commission and many countries, such as Italy, Spain, Roumania, Russia, the Balkans, Palestine and the United States of America have been visited. The advantages of such tours are easily understood : they allow an exchange of ideas with local workers, on the spot where their investigations have been carried out. In this way an understanding is reached about various points which had previously been discussed in an inconclusive manner at conferences, or in which the discussion was without result because of the absence of a concrete basis.

It is hardly necessary to explain why British India constitutes so favourable a field of study for such an expedition. The history of the parasitology of malaria of which the famous opening chapter was written at Constantine and the second in Italy was completed in India. We considered ourselves very fortunate in having an opportunity of visiting the places where Sir Ronald Ross made his discoveries, where Christophers and Stephens, James and Liston, Bentley and many other veterans worked or are still working, and we expected to make a rich harvest of scientific material.

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* These notes formed the subject of a lecture in French delivered at the Second Congress on Paludism in Algiers in May 1930, and have been translated from the manuscript of the author by Lieut.-Colonel J. A. Sinton, Director, Malaria Survey of India.

In the course of this meeting it falls to me to give you a brief account of the actual state of malaria in British India, as gathered from the personal impressions of the Commission.

From Bombay our programme took us northwards to the Punjab, where we visited the Ross Field Experimental Station for Malaria at Karnal under the control of Lieut.-Colonel Sinton, and the Central Research Institute at Kasauli directed by Colonel Christophers. There we were able to study thoroughly the different local problems of malaria in India, by the aid of the large collections and thanks to the help of our expert colleagues attached to these two institutions—Covell, Barraud, Macdonald, Bruce Mayne, Puri and Khazan Chand.

At Simla General Graham, the Public Health Commissioner with the Government of India and Secretary of the Indian Research Fund Association, made us very welcome and showed a deep interest in our visit.

From the Punjab our programme led us eastwards through the Imperial Province of Delhi, the United Provinces and Lucknow, to Calcutta and further still to Assam, the centre of kala-azar ; then crossing the Bay of Bengal we visited Rangoon and the interior of Burma. From Rangoon we took a steamer back to India and reached the province of Madras. Lastly, having visited the Indian State of Mysore, we returned to Bombay, our port of departure.

On account of its geographical position, India affords a great diversity of conditions suitable for the occurrence of malaria. The country extends northward to a latitude equal to that of Northern Africa, and to the south it is only separated from the equator by 10 degrees. The malarial conditions are far from being the same everywhere ; on the contrary they differ markedly in different areas. Among the factors which influence the importance of malaria, climate plays an important rôle. In the north a well-marked winter leads to a seasonal regression of the disease, while in other regions it is the dry weather which has an analogous influence. But, apart from climate, the orography and the physical properties of the soil are not without influence on the epidemiology of the disease. There is nothing extraordinary in this ; in this vast continent with the highest mountains in the world, with immense plains, with large rivers. one would expect physico-geographical conditions of a most diverse character. Nevertheless, these conditions in general do not differ markedly from those found in other countries, and it is consequently useless to enter into details.

Apart however from these generalities, malaria in India shows some special features which may be said to be characteristic of this country. These are the types of malaria seen in the Punjab and in Bengal, the malaria of the ' Terai ' and that of urban areas. I propose to discuss these four problems in the order mentioned.

In the Punjab we find ourselves in one of the greatest provinces in India, peopled by twenty-two million inhabitants. Here the rainy season lasts from the end of June to the beginning of September. It makes itself felt with a varying intensity from year to year. It is followed by an autumn without rain,

which commences in September with great heat, aggravated by a very high humidity caused by the moisture given off from the soil, saturated by the previous rainfall. At the end of October the temperature begins to fall. Then the absence of continued rain, the drying up of the surface water which results, and the low temperature, put an end to the development of Anophelines. This recommences early in spring when the temperature begins to rise again, but is quickly suppressed by the excessive dryness of May and June. It is only with the advent of the rainy season that the Anopheline population re-establishes itself. The season of maximal malarial intensity occurs during the months of September and October. The intensity varies from year to year. There are periods of 5 or 6 years during which malaria is of a mild nature and not widespread. These periods are separated from each other by one or two years with severe malaria epidemics, which raise the mortality rate as much as ten times normal. The cause of these epidemics is still imperfectly understood. Among other factors one seeks the cause in the nature of the rainy season, which ought to influence the number of Anophelines (chiefly *A. culicifacies*). The early appearance of the monsoon gives the Anophelines a longer period in which to multiply, and the sporozoites more time to mature in the mosquito. There is, however, no doubt that other factors of a very different nature influence it equally.

In other parts of the province there are irrigation works, which are of primary importance in causing malaria to be maintained in a more or less endemic condition. The irrigation canals, situated on a higher level than most of the adjacent country, have caused a rise of the subsoil water table in these areas, with the result that they have become saturated with water even to the extent of forming definite swamps. This results in the production of numerous breeding places for mosquitoes. One sees here the elements of a veritable tragedy : the absence of water renders the earth unfertile ; irrigation leads to rich crops of grain but also of Anophelines. The Irrigation Department is faced with a problem worthy of its steel, for on its solution depends the health of the people. They are attempting to solve the problem by adding to each irrigation system a suitable drainage system, a method which had been neglected in the past. While awaiting the results of these measures, Colonel Gill, the Director of Public Health in the Punjab, with his deep and thorough knowledge of the situation, has organized a distribution of quinine, as complete as possible, during the months of increased malarial incidence.

In the province of Bengal we met the second of the problems mentioned above, where the conditions of malaria are exactly the opposite of those in the Punjab. In the delta of the Ganges and Brahmaputra, malaria is slight everywhere where the subsoil water table is very high. It is prevalent only where the table is at a lower level. It is in these areas, slightly raised above the plains, that the disease occurs in a most severe fashion, while the lower plains, swampy and flooded during the rainy season, are perfectly healthy. The regions which are now malarious in Lower Bengal were formerly as healthy as the other parts. It is only during the course of the nineteenth century that the present situation has developed. Dr. Bentley,

who has made the malaria of Lower Bengal the object of a prolonged study during the last 10 years, continues to make strenuous efforts to return these malarious regions to their former condition of healthiness. To him this problem, which involves the health of many millions of people, is one of the most important in the whole world. In his book ' Malaria and Agriculture in Bengal ' (1924) he has set forth his ideas. This book has been familiar to us since the First Malaria Congress in 1925, but I must confess that our Commission could not help feeling a certain scepticism about Bentley's views, which were so contrary to all our own experiences. But eight days of personal observation under the guidance of Dr. Bentley were sufficient to make us admit that there was a good foundation for his point of view. This is a very convincing illustration of the value of such a tour as this.

It is, however, necessary that Bentley's views should be explained in greater detail.

The immense delta of the Ganges and the Brahmaputra is in a continual state of change ; thus some branches of the river may be obliterated this year and others similarly at a later date. But these changes are insignificant compared with those which have been effected by the intervention of man who builds embankments, roads, railways, canals, bridges, etc.—works which tend to make the free flow of the water very difficult, and to facilitate the blocking of one or more branches of the river. It was believed that this could be done with impunity because there still remained many other branches to carry the water of the Ganges and the Brahmaputra to the sea But this is an erroneous view, for the water of those branches of the river through which the water of the Ganges flows freely, ' living rivers,' are muddy and loaded with silt. This silt, deposited on the land during floods, not only fertilizes the fields but is also very destructive of aquatic vegetation. The result is that ' living ' branches of the river do not contain aquatic vegetation and cannot act as breeding places for Anopheline mosquitoes. But the blocked branches of the river (' dying rivers '), which do not contain water derived from the Ganges have an entirely different character. The water there is stagnant or only flows slowly in proportion as it is augmented from the subsoil water and the rains. It is clear and covered with a dense aquatic vegetation, both vertical and horizontal. These ' dead ' rivers form very beautiful landscapes worthy of a Ruysdael ; but from the sanitary point of view they have a very different aspect : they form dangerous breeding places for the Anophelines which carry malaria (in this area *A. minimus* var. *varuna* and *A. philippinensis*). It is from these causes that towns like Jessore, Murshidabad, Birnagar, Berhampore and Krishnagar, which were formerly in a flourishing state, have fallen into decay, and are inhabited by only one-tenth of their former population. We see repeated in our own times and under our own eyes, the old history of the royal town of Anchor lying in ruin in the forests of Indo-China—a region rich and populous turned into a desert or a forest by the baneful influence of malaria.

To these unfortunate sanitary conditions is added another circumstance, no less unfavourable. The blocking of the rivers and the construction of embankments

has put an end to the periodic inundation, which formerly covered the country with a layer of silt, provided by the waters of the Ganges, which acted as manure. The absence of this natural fertilizer has caused the crops to become less and less abundant. Thus the same causes have led to both poverty and malaria.

Since the economic aspect of the problem in Lower Bengal has become well recognized, the hygienist no longer finds himself alone in his efforts ; he is supported by the agriculturalist. Lower Bengal needs an agricultural 'bonification' just as much as a sanitary one. Dr. Bentley is fortunate in the fact that his original and long-sighted plans have brought him such allies, who have financial resources which a simple hygienist could never obtain. Dr. Bentley wishes to revive the 'dying' rivers so that they again receive, as in the past, the silt of the Ganges, and form part of a well-controlled system of irrigation. The rich natural manure, suspended in the water of the Ganges, should not go to waste in the sea, but should serve to return the fields to their ancient state of fertility. Now that one of the most famous irrigation engineers, Sir William Willcocks, has placed his advice at the disposal of Dr. Bentley, we hope that the country is going to profit by the plans of the latter. There are only some details of technique and questions of finance which stand in the way of the immediate realization of the scheme. We are in agreement with Bentley when he asks that a commission of experts from all countries should decide whether the execution of his scheme is feasible or not. Such a decision, affecting a problem of so immense a nature, is no longer in the competence of a single person. even if he is the head of the Irrigation Department in India.

Our third problem was encountered in the country at the foot of the Himalayas called the 'Terai' in Rohilkhand and in Bengal as far as the Teesta River, beyond which the same type of country is known as the 'Duars.' These regions, situated at an altitude of about 250 metres, are usually very fertile and at the same time very unhealthy because of the deadly endemic malaria. Here we found very high spleen rates, often reaching one hundred per cent, and the degree of enlargement of individual spleens was everywhere remarkable.

It is difficult to give an account of the epidemiological conditions of these areas, because they are inhabited by two very different races of people ; on the one hand, an indigenous population, the *Buxas* and *Tharus*, with distinctly Mongolian characteristics, and on the other, a population of immigrants from the plains, the *Desis*.

The Buxas and Tharus live in villages widely separated from each other. The spleen rates in the children approached 100 per cent and those of the adults were also very high. In spite of this, their physical condition compares favourably with that of the immigrants ; they do not seem to suffer so much from the effects of malaria as the latter do. However, the small number of children found among them seems to show that heavy sacrifices are taken from them for the privilege of living in this country.

The explanation of this state of affairs is as follows. Soon after birth the children are exposed to malarial infection by the local strains of parasite. This

results in a considerable degree of immunity among the children who survive, an immunity at first purely anti-toxic, but which later becomes anti-parasitic. In the course of years the number of parasites in the blood becomes less and less in spite of continual re-infections, while the growing immunity hastens still more the disappearance of gametocytes. Christophers has demonstrated the occurrence of this phenomenon in British India, and his observations agree with those made in Sumatra. A perfect immunization, i.e., a complete return to the normal state, is found only among a small minority of the inhabitants; as in Sumatra, splenic enlargement persisting during adult life bears witness to the sufferings from malaria endured in youth.

In these areas of hyperendemic malaria during the last 70 years a Desi population has settled down, attracted from the over-populated plains by the lure of abundance of fertile land. The effect of the local malaria on these immigrants has been most unfortunate. Their miserable physical condition, a spleen rate often reaching 100 per cent even among adults, the degree of splenic enlargement, the excessively high mortality both general and infantile, all bear witness to a poorly developed state of immunity. The population is only kept up by uninterrupted recruitment from the people of the plains. It is because of this immigration of people from relatively malaria-free areas that it is possible to have in the Terai a condition of acute epidemic malaria side by side with the endemic form. It is probable also that the state of relative immunity develops more slowly among the immigrants, because they have only become subject to repeated malarial infections at a more or less advanced age, and not from birth as is the case among the indigenous inhabitants. Finally we must consider the possibility of the importation of strains of parasite directly from the plains. These strains, stimulated to an exaggerated multiplication, or even virulence, through the influence of the local Anopheline vectors (such as *A. listonii*), could explain the conditions of more severe malaria among the Desis, without having recourse to the hypothesis of a racial immunity among the indigenous people.

There still remain many points to be investigated in this area. The Commission is of the opinion expressed by their English guides, that the problem of this immunity requires extensive new investigations. These researches should be still more interesting because of the remarkable fact that blackwater fever, so widespread in the Duars, is absent in the Terai districts of Rohilkand, of which we have been speaking.

Coming now to urban malaria. In the majority of infected countries, malaria is a rural problem. The large towns are only affected in their peripheral portions in proportion to the influence of the neighbouring rural areas and the distance of flight of malaria-carrying mosquitoes. A type of malaria which has its origin in the town itself and spreads in distinctly urban areas, is a very extraordinary phenomenon. It was Liston in 1908, who first showed in the wells of Bombay the occurrence of the larvæ of a dangerous malaria-carrier, *A. stephensi*. The genus *Anopheles*, formerly thought to breed only in pools of stagnant water, but later

recognized as breeding also in water with a more or less rapid flow, here showed quite a different character. For the purpose of laying its eggs, *A. stephensi* descends to the clear water of the wells, which are present in the courtyard of every house. The depth (as much as 18 feet) and the darkness are no obstacles. This, however, is not the limit of its feats. It will fly to the roofs of the highest buildings to lay its eggs in water receptacles, called cisterns, which are found everywhere there. This peculiarity is the difference between the conditions in Bombay and those seen in Jerusalem, where *A. bifurcatus* also causes urban malaria. Liston's discovery was followed by the classical study of Bentley, who in his report discussed in great detail the anti-malarial measures which should be taken. This report concludes with the words: 'Not only can malaria be reduced, but it can be absolutely eradicated from the greater part of Bombay.'

The measures recommended consisted chiefly in a more suitable construction of the wells, and in measures to close wells and cisterns in such a way as to prevent the entry of Anophelines. These measures were simple, their justification was clearly shown, and the cost of their execution was not great, so that the town immediately began to put them into practice and continued to carry out these sanitary measures for some time. But after some years the enthusiasm died down, the campaign was pursued in a less and less energetic manner, and finally was completely suspended, until the time when, during the third decade of the present century, a fresh outbreak of malaria re-awakened the interest. Since that time, Christophers in 1922, Houston in 1925 and above all Covell in his admirable report of 1927, have vainly tried to have Bentley's recommendations properly carried out, for they were able to accept them without any great modification. In spite of the facilities for a complete eradication of malaria in a very populous area and one entirely covered with urban dwellings, where it is not necessary to extend the operations to zones of several miles, in spite of the certainty that the expenditure would be amply compensated for by the fall in the morbidity and mortality rates, the Commission was astonished to find that the eradication of malaria in Bombay was still being awaited.

What is the cause of this state of affairs? It is necessary in the first place to speak of the opposition of the people to measures which interfere with their wells. They believe that air and sunlight should reach the water of these wells in order to keep them pure. For this reason they do not like to have the wells hermetically sealed, and often they show active opposition. Our Commission endeavoured on several occasions to convince one of the Municipal Commissioners, the leader of the opposition, of the error of his views.

On account of these religious prejudices the public health authorities have cautiously refrained from substituting the use of paris green, a very simple measure, for the hermetical sealing of wells, because people might say that this was a cause of poisoning and this would rapidly stop all sanitary measures. At least the educated Indians should use their great influence to combat this spirit of opposition, for the sanitarian can do nothing.

It should be noted, however, that the excuse of 'popular opposition' is not valid in the case of wells, cisterns and other collections of water existing on the premises of factories, in industrial quarters, at the port and on the railways. The neglect which is observed here, forms a grave accusation against the railway and port authorities, who are outside the jurisdiction of the Municipality.

What is lacking here is interest in public welfare and the goodwill to promote it. Major Covell in his report has rightly pointed out that there should be a co-ordination between the four great authorities interested, but which are independent of each other—the provincial government, the city municipality, the port authorities and the railway authorities, in order that a campaign may be started against a state of malaria which is purely 'man-made.' At the time when we left India at the end of December 1929 this collaboration had not yet materialized.

Analogous conditions are present in other large towns. They probably explain the cause of an epidemic of malaria which broke out in the centre of Lucknow during the course of last summer (1929). At Bangalore the wells breed *A. stephensi* in the same way, but in this town the Commission saw with satisfaction that the wells had been treated with paris green without any opposition from the inhabitants. An energetic and intelligent municipality is the most efficacious protector of public health.

I now propose to approach another aspect of the subject: that of malaria among special groups of population, such as the Army, the railway staff, workmen on large hydraulic projects, and coolies on plantations. The success of a campaign against this scourge is often an indispensable condition for the existence of such enterprises. The population which enjoys the protection afforded by such a campaign is not a natural population of normal composition. It is composed of elements forming artificial groups, and subject to a regime which is more or less different from the usual. Health must be preserved among these groups irrespective of cost, and the question of expense has only a secondary importance. So the sanitarian can undertake a very energetic campaign against the disease. We have seen excellent examples of such anti-malarial activity in the tea plantations of Assam, especially in Cachar where Dr. Ramsay directs the work; Mr. Senior-White has shown us in Orissa, in the Nagavali Valley and at the Vizagapatam Harbour Construction Works, very efficacious anti-malarial measures to protect the railway workmen on the branches of the Bengal-Nagpur Railway. Into this category falls the protection of 15,000 workmen and their families employed on the construction of the Cauvery Dam at Metur, which is being carried out by Dr. Massilmani. It would, however, be an injustice to the efforts made in the different provinces, if one attached too exclusive an importance to these examples of industrial campaigns, which, however encouraging they may be, are too costly to become the basis of a widespread campaign among the people.

Of the larvicides, oil is the most frequently employed. There is a great diversity of opinion as to the choice of oils and the mode of their employment. The use of paris green is limited to some small areas. Demonstrations given

by our colleague, Dr. Williams, will encourage a continuation of trials with this method.

Even if the use of paris green becomes very much extended in India, I do not believe that it will prove the solution of the malaria problem. If I may be allowed to express a personal opinion. oil, paris green and quinine are only palliatives which we cannot yet do without. But the future lies in biological methods of which Nature has shown us some examples. In this statement I do not imagine that I am propounding any new idea. These have already inspired Bentley, when he followed the example of Nature in realizing the conditions which exist in an area rich in Anophelines but free from malaria. Irrigation and drainage, more especially subsoil drainage, are biological methods. So also is the method which produces periodically in the course of a slow-running stream a torrential flushing which washes away the larvae. We have seen an example of this method on a large scale in the River Gumti at Lucknow, where a barrage across the river is opened periodically and allows the escape, into the almost dry river bed below the dam, of a large volume of water, about a metre in height, which had been held up by the barrage. These methods act like the torrential rains do in nature.

I would remind you also of the fundamental observations made by Christophers in the Andaman Islands showing that the felling of jungle, often considered—and rightly so—as an important anti-larval measure, can have an entirely opposite effect in encouraging the multiplication of that dangerous mosquito, *A. ludlowii*, which likes sunny breeding places By cutting down the forest one destroys the natural protection against malaria. Strickland's researches confirm those of Christophers and open up the way for a new type of anti-larval campaign, directed against *A. minimus* and *A. maculatus*, which breed in mountain streams. This is done by growing thick hedges along the margins of the streams, so as to throw the water surface into very dense shade. This is a purely biological method which will be very useful in a campaign against malaria in mountainous districts, provided it is successful. Apropos of biological methods allow me to add that in the Dutch East Indies they have been successful in working the fish ponds in such a way that fish can be bred without Anophelines. Dr. Walch has described this to you. One should also note the part played by enemies and diseases of larvæ, which may possibly be of great importance in British India. Knowledge of this subject is still scanty, but Sinton and Iyengar are trying to increase it.

Before finishing I wish to mention some problems, as yet imperfectly solved, which have attracted our attention during the visit. I have already alluded to the lack of precision in our knowledge of immunity in endemic malaria, notably with regard to the spleen rate in adults. It is said that among the African negroes, the adults no longer have splenomegaly, but in the hyperendemic areas in Sumatra and also in those of British India, splenic enlargement persists in adult life, in spite of the fact that numerous repeated re-infections each year give the best opportunities for the development of immunity. Is this due to a special immunity in the negro race or is it because we cannot compare the conditions in Africa with those in India ?

The study of prolonged latency in malarial infections is well known at present in Europe, thanks to the researches of Kortweg, Swellengrebel and James, but has not yet been approached in the Indies.

Then there is blackwater fever. One is easily satisfied if one believes that it is merely a complication of malaria in places where the incidence of the disease is sufficiently high. The Commission has been able to satisfy itself that the distribution of this disease in the malarious regions of India is clearly opposed to such a view. Blackwater fever is observed in some areas where the spleen rate hardly reaches 50 per cent (the limit of hyperendemicity according to the classification of Christophers), as was the case in Lashio, Potanghi and Koraput. It was absent in other districts, such as the Terai of the United Provinces, where the spleen rate went as high as 100 per cent and where it ought to have been present according to the current view. In obstinately upholding such a view, which I consider foolish, one is stopping progress which might lead to a solution of the problem, which will not be solved if one interests oneself in its biochemical aspects only.

Epidemiological experience makes it at least probable that malaria with a tendency to blackwater fever has a different etiology to the type of malaria which never shows this complication. This is a point on which Sir Patrick Manson himself always insisted.

This idea of a different etiology may involve the recognition of the existence of a specific *Plasmodium*, which provokes the clinical syndrome. Sinton has told us his opinion, based on a considerable experience, that there seems to be a remarkable correlationship between the geographical distribution of *Plasmodium tenue* Stephens in India on the one hand and that of blackwater fever on the other. For this reason he thinks this parasite suspect as a provocative of malaria with a tendency to blackwater fever. One must also consider the possibility of a combined infection of the *Plasmodium* and some other parasite, such as the genus *Bartonella*, etc.

Again a certain species of mosquito may be capable of modifying the characteristics of the parasites, which pass their amphigonic development in its body, in such a manner as to make them more apt to provoke blackwater fever. It has been shown that there is a modification of the virulence of the yellow fever virus caused by passage through *Aëdes albopictus*. It is therefore not unreasonable to suppose that an analogous influence may occur in the relationship between the *Anopheles* and the *Plasmodium*.

It is not even necessary to suppose that this harmful influence on the virulence of the parasite must be exercised by a species of *Anopheles* markedly different from other species. It is very possible that it may be caused by races or varieties of some of the well-known species of *Anopheles*. The workers at Kasauli have recognized the increasing importance of a study of the different varieties of various species of *Anopheles* previously thought to be identical. Strickland and his collaborators, on the contrary, guided by considerations more entomological than epidemiological, have tried to group these varieties into a single species, as they have already done in grouping *Anopheles minimus, A. aconitus, A. listonii* and *A. varuna* under the

specific name of *funestus*. We are afraid that this procedure will only create confusion, because we know from the researches of van Thiel and Swellengrebel that there exist races of *Anopheles*, scarcely capable of differentiation by their morphological characters, but nevertheless very different from the biological and epidemiological points of view (Swellengrebel). In the case where the morphological characters allow of a differentiation, it is important not to neglect these because of considerations to which the systematist may attach value but which do not fit in with the epidemiological findings.

This point of view is justified by the study of other species. *A. subpictus* (*rossi*) has never been found infected in British India, while in Java we have to admit that it is a carrier of some importance. *A. hyrcanus* (*sinensis*), unimportant in British India, assumes an increasing importance in the Dutch East Indies, where Walch considers it as one of the most important carriers of malaria. *A. philippinensis* is recognized as a very important carrier in Lower Bengal, while it has never been found infected in Assam.

To solve these puzzles it becomes necessary to investigate anew those species of *Anopheles*, considered until now as homogeneous, in order to determine if the biological differences are not related to morphological differences, hitherto unrecognized.

However this may be, the importance of differences in the biology of Anophelines is shown by these new observations collected through the collaboration of workers in several different countries. The epidemiology of malaria is founded upon the biology of *Anopheles*, and this biology is still imperfectly known, as the Commission has been able to convince itself clearly during its sojourn in India.

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REPORTS ON SOME SHORT MALARIA SURVEYS UNDERTAKEN IN KATHIAWAR.

BY

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[April 1, 1931.]

CONTENTS.

INTRODUCTION.

AT the invitation of Major J. B. Hance, O.B.E., I.M.S., Agency Surgeon, Western India States Agency, an investigation of the mosquito nuisance and the prevalence of malaria was undertaken in several areas in Kathiawar, Bombay Presidency.

Very little seems to have been recorded previously about these conditions in Kathiawar. The Gazetteer of the Bombay Presidency (1884) (Vol. VIII, Kathiawar) says that 'the malarious damp heat of October and November makes these months the sickliest season of the year. During the cold weather, November to March, fever continues but changes to the tertian and quartan type.' In this book it is pointed out that the years of greatest rainfall are the years of highest 'fever' incidence, while in years of small rainfall the 'fever' rate is low.

Colonel J. McCloghry, I.M.S., in a report on malaria in the Bombay Presidency made in 1908,* states that 'Kathiawar, like the Deccan, is comparatively free from malarial conditions.'

It is noteworthy that in 1884 the relationship between rainfall and 'fever' prevalence in Rajkot was observed, although at that time the connection of the mosquito with the spread of malaria had not been discovered. The observation

* Govt. of Bombay G. O. No. 10342 of 1908.

that the type of 'fever' changes from the remittent type to the intermittent tertian and quartan forms during the months from November to March is interesting. It may be explained by the fact that fresh infections, which were being acquired during the months of August, September and October, are more likely to show fever of a remittent character. Relapse cases seen at later periods of the year, when fresh infections have decreased markedly in number, are more liable to show an intermittent character with either tertian or quartan periodicity. At the same time the malignant tertian fever, so prevalent in the autumn, shows remittent more commonly than intermittent pyrexia in its acute stages.

The visit to Kathiawar was made in April, which is the driest season of the year,* and almost the least malarious. Unfortunately force of circumstances prevented a visit being made later in the year. It was not possible to make complete surveys in the time available (16 days), but visits were made to Rajkot, Junagadh. Bhavnagar and Wadhwan. In view of the paucity of our information about malaria in this part of India, the results of these investigations, although incomplete, seem worthy of record.

Part I.

THE PREVALENCE OF MALARIA AND MOSQUITOES IN RAJKOT.

A short investigation was made into the prevalence of malaria and mosquitoes at Rajkot between 11th and 16th April, 1929. As this was the dry season of the year, it is not considered that the survey was nearly complete. Further and valuable information would probably be obtained if a longer survey were made at the end of the wet weather.

A. Topography.

The geographical position of Rajkot City is 20° 18′ N. and 70° 50′ E. The City and Civil Station lie on the left bank of the Aji River at a height of about 470 feet above sea-level. The City occupies the southern portion of this area, and is surrounded by the Civil Station on its northern and western boundaries. A rough sketch map showing the position of the various features of malarial interest has been appended.†

The population of the City is about 36,000 and of the Civil Station about 12,000. The houses in the City are crowded together with few open spaces, while the Civil Station, except for the Suddar Bazaar, is composed mainly of bungalows with large compounds. The terrain is slightly undulating, with a considerable slope towards the river. The ground is mostly bare and there is little or no jungle. The surface soil is shallow and, in most parts, rock is reached at the depth of a few feet.

The area was examined to ascertain the chief actual and potential breeding-places of mosquitoes. The sources of water may be classified as follows: (1) The

* Some normal meteorological records for Rajkot and Bhavnagar are given in Appendix I. These give some idea of the conditions prevalent in this area.

† Not reproduced.

Aji River; (2) Various nullahs; (3) Water supply; (4) Water storage; (5) Irrigation; (6) Waste water; and (7) Rain water.

(1) *The Aji River.*

This flows northwards along the eastern boundary of the area. Its bed is rocky, with banks about 15 to 25 feet high. It is a perennial stream flowing in a wide bed, most of which is dry in April At the time of the visit the water level was low, and the main stream was running through a series of rocky pools. There were also numerous side pools off the main stream, either stagnant or with a gentle flow. Although there was little vegetation in the main stream, there was much grass, water-weed and algae in the side pools, forming ideal breeding-places for mosquitoes.

Opposite the City the river is extensively used for washing clothes, and a number of storm and waste-water channels from the City empty into its bed. In many instances these form dirty stagnant swamps. The river is crossed by a road bridge at the north end of the City, and a few hundred yards lower down there is a railway bridge. Opposite the Jail it is again crossed by an aqueduct, which carries irrigation water from the east bank to fields outside the north end of the Civil Station.

The river immediately north of the road bridge is joined on its left bank by a large nullah, formed by the junction of Nullahs A and B (*vide infra*). At the point of junction this nullah discharges into a large number of grassy pools and swamps before joining the main stream This extensive breeding ground is immediately below the high bank on which is situated the West Hospital.

In the portion of the river bed between the Road Bridge and the Aqueduct, there are many pools with much vegetation in them, some with a little flow, some stagnant. Along the bank in this locality are some small areas of seepage, chiefly opposite the ends of storm-water nullahs. These nullahs were dry when inspected, but it is probable that during the rains the areas of seepage will be greatly increased.

(2) *Nullahs.*

There are three main nullahs in the area under consideration. These appear to form the natural channels for the drainage of storm water, and are probably full of water during the monsoon. In April when examined, they only contained water towards the lower halves of their courses. This water seemed to be mainly of subsoil origin, but it was augmented by sullage from waste-water drains. The amount of water is also probably increased by seepage water from the soakage pits for waste water, which are the main means of disposal of such water in this area. For ease of description these nullahs have been designated A, B and C.

Nullah A.—This bounds the south side of the Civil Station and runs through the City to join Nullah B. At the time of inspection, this nullah was dry in all its upper course, but towards its termination, where it received much waste water, showed a sluggishly running stream with many grassy pools and swampy areas in its bed.

Nullah B runs through the south end of the Civil Station more or less parallel with Nullah A. After flowing between the City and the Civil Station in the lower part of its course, it unites with Nullah A near the north end of the City, and terminates in the Aji River below the Road Bridge. It was found to have a dry, rocky bed almost as far as the R. C. Church. Below this point water was present, flowing through the rocky bed and forming many stagnant and very grassy pools. Towards its termination it forms a wide swampy nullah with much vegetation and many pools.

Nullah C runs along the west and north sides of the Civil Station, and enters the river at a considerable distance beyond the Police Lines. It was dry in the major portion of its course, but near the Jail and Police Lines it contained a number of deep isolated pools, full of aquatic vegetation. In this portion of its course it runs close to the irrigation channel which crosses the river by the Aqueduct. I am informed that when this channel is running full there is a great increase in the amount of water in the nullah.

(3) *Water Supply.*

There is a piped water-supply to both the City and the Civil Station. This supply was installed about 25 years ago, prior to which water was obtained from wells and from the river. Since the introduction of this supply many wells have fallen into disuse, but numbers are still used for irrigation and washing purposes, while a few are used for drinking water. These wells vary in diameter from 15 to 30 feet and extend through the surface soil into the rock beneath. The water level is about 20 to 30 feet from the surface. A number of the wells have been covered in, but the coverings and manhole lids have become broken, while many of the disused wells have no covering. I am informed that the disused wells have not been filled in for various reasons, such as expense, use for irrigation, or religious purposes. They are also supposed to be a reserve in case of failure of the piped water-supply.

(4) *Water Storage.*

There is a large 'kutcha' tank near the Suddar Bazaar, which is filled during the rains by a channel from Nullah B. This was dry in April but some wells on its banks contained water.

There are, in the more populous portions of the area, a number of raised stone reservoirs connected with the piped water-supply. The water from these is distributed by a series of taps at their bases. These reservoirs are closed at the top, except for inspection manholes which are covered with wire gauze.

In the compounds of most bungalows are 'pukka' cement tanks of varying sizes, for the storage of water either from the piped supply or from wells. This water is collected for gardens, washing, etc. Several bungalows have fountains and ornamental ponds in their gardens.

(5) *Irrigation.*

The only irrigation found inside the area was from wells. When examined the water did not seem to be used in excessive amounts, and the irrigation channels appeared to dry up within a few hours after use. This, however, may not be the case in the wetter months of the year.

As mentioned previously, there is a large irrigation channel running along the edge of the Railway about 100 yards west of the Police Lines and Jail. This channel irrigates fields just outside the northern end of the Civil Station. There are a number of low-lying areas below the east bank of this channel, which would appear to be swamps when the canal is being used. As pointed out above, the seepage from this channel affects the amount of water in Nullah C near the Police Lines.

(6) *Waste Water.*

In many places there is no provision for waste water from taps, and it forms stagnant pools in the vicinity The waste-water drains from the City, etc., in many cases discharge into the beds of the river and of the nullahs. There is no proper connection with the main channels of the streams, with the result that filthy, grass-grown swamps are formed. Many of the drains are blocked and have stagnant pools in them.

There is a large 'pukka' waste-water drain running along the slope of the east bank of the river below the West Hospital, extending from the Road Bridge almost to the Aqueduct. Here it empties into the river bed forming stagnant pools and swamps. There are a number of pools in the river bed below and parallel with this drain to the south of the Railway Bridge.

The main means of disposal of waste water in large portions of the area is by soakage pits. As mentioned above, the large amount of water going into these probably has an effect in increasing the subsoil water, and thus the amount of water in the different nullahs in the vicinity. These pits in most cases seem to work well, but several were seen which were pools of filthy water due to blocking.

Many bungalows, etc., have cement sumps for waste water from the cook-houses and bath rooms.

(7) *Rain Water.*

As the visit was made during the dry season, no opportunity was available for studying the formation of pools during the wet weather. As far as could be judged from the slope of the ground, no difficulty should be experienced in maintaining proper drainage to prevent pool formation after rain, especially as the average annual rainfall is only about 24 inches. The roadside storm-water drains have a good slope, but will probably require regrading in places to prevent pool formation. Borrow-pits in the area seemed few in number.

The sumps for water-storage and waste water in empty houses may become filled with water during the rains. This may stand for long periods.

B. Mosquitoes of the Rajkot Area.

The mosquitoes of this area must be considered from two standpoints, namely, the carriage of disease and the nuisance produced by their bites. From the former point of view the Anopheline mosquitoes in relation to malaria are the most important.

The following species of Anopheles were found in Rajkot :—*A. culicifacies*, *A. stephensi*, *A. listonii*, *A. subpictus* and *A. turkhudi*. The first three species mentioned are probably the three most dangerous carriers of malaria known in India. As the duration of the visit was brief, and made at a time when mosquitoes were less prevalent than in the autumn, it is almost certain that other species of Anopheles are also present, and possibly more numerous, at other seasons.

The Culicine mosquitoes found at Rajkot were *Culex fatigans*, *C. vishnui* and *C. bitaeniorhynchus*.* *C. fatigans* is known to be a carrier of filariasis, which has been recorded around the Gulf of Cambay. It is possible that these Culicines may also be implicated in the carriage of dengue and similar short fevers. Apart from mosquitoes acting as carriers of disease, they may be a pest by reason of their bites, and very large numbers were found breeding in close proximity to dwellings.

(1) Breeding-places of Mosquitoes.

On the attached Sketch Map† are given numbers, which refer to many of the principal breeding-places found in the area. These breeding-places are listed in Appendix II. It must not be thought that these are the only breeding-places in the Rajkot area, for it was impossible in the short time of the visit to find all the dangerous places. Those found give a good indication of what may be expected where similar conditions exist in any part of the locality.

(a) Breeding-places in the River Bed.

The main stream of the river does not appear to act as a breeding-place, on account of its rapid flow and the amount of disturbance of the water by dhobies (washermen). The backwaters and pools along the bed, however, more especially those with grass and other vegetation are acting as large nurseries of both Anopheline and Culicine mosquitoes. Those pools with vegetation and a gentle flow of cleanish water give rise mainly to *A. listonii* and *A. culicifacies*, while the more stagnant clean pools, although producing *A. culicifacies*, mainly breed *A. stephensi*.

Breeding-places were present in large numbers all along the river bed. The dirty pools soiled by sewage and washing water, while not giving rise to larvae of the more dangerous malaria-carrying Anophelines, produce innumerable Culicines and *A. subpictus*. The Culicines found here were *C. fatigans*, *C. vishnui* and

* I am deeply indebted to Captain P. J. Barraud, F.E.S., F.Z.S., of the Malaria Survey of India, for the identification of the Culicine mosquitoes mentioned in this paper.

† Not reproduced.

C. bitaeniorhynchus. These, while not dangerous as carriers of malaria, must cause a great nuisance.

(*b*) *Nullahs.*

These were breeding both Anophelines and Culicines in great profusion along the whole of that portion of their courses which contained water. In the upper parts of their courses they were dry in April, but would probably have much water during the rains. At the latter period they would probably not act as breeding-places, the flow of water being too rapid, but when the rains stop and the water begins to fall, larvae would be found in the pools left.

With the introduction of a piped water-supply to the area the amount of water in the nullahs has increased. This is due to the fact that waste water has been allowed to flow directly into the nullahs, or more commonly into soakage pits. The latter causes a resulting increase in the level of the subsoil water, and indirectly of the amount in the nullahs.

The Anophelines found breeding in these nullahs were :—*A. culicifacies*, *A. listoni*, *A. stephensi* and *A subpictus*. The Culicines were *C fatigans*, *C. vishnui* and *C. bitaeniorhynchus*.

(*c*) *Water Supply.*

The majority of wells which are in constant use do not seem to be breeding mosquitoes in any quantity ; whether they do so at other times of the year should be investigated. Disused wells, especially those without covers. were found breeding *A. stephensi* and *C. bitaeniorhynchus*. This was more especially the case in wells in which the surface was covered with floating debris. These disused wells are scattered all over the area, and must form the source of many malaria-carrying mosquitoes especially during the dry season, when other breeding-grounds have dried up.

(*d*) *Water Storage.*

The large stone reservoirs did not seem to be breeding mosquitoes, although the wire gauze over the manholes was of a mesh which would not exclude all species. These reservoirs should be examined at other seasons of the year.

The 'pukka' cement tanks in the compounds of bungalows were found in several instances to be swarming with the larvae of both Anopheline and Culicine mosquitoes. The Anophelines were represented chiefly by that dangerous malaria carrier, *A. stephensi*, which was thus multiplying in large numbers in close proximity to dwellings. Some of the fountains and ornamental ponds were breeding both *A. culicifacies* and *A. stephensi*. Those in which there were gold-fish were not found to contain larvae.

When the large 'kutcha' tank near the Suddar Bazaar is filled, it will form a potential breeding-ground.

(*e*) *Irrigation.*

No larvae were found in the irrigation channels from wells in April because they dry up rapidly in a couple of days. These channels should, however, be

watched during the cooler and wetter season, when water may stagnate in them for some days, so permitting the development of larvae.

The low areas beside the irrigation canal at the Police Lines probably act as dangerous breeding-grounds when filled by seepage or rain water.

(*f*) *Waste Water.*

The sumps for waste water outside houses do not usually breed Anophelines when fouled by dirty water, but have been found to breed Culicines. These sumps in empty houses, where not fouled by waste water, may become filled with clean rain water and allow the breeding of both Anophelines and Culicines.

The soakage pits, when working properly, do not seem to breed mosquitoes, but, when allowed to become choked and form stagnant pools, they are a fruitful source of the mosquito nuisance. Some of these sumps held such numbers of Culicine larvae and pupae that the surface of the water was black with them. These must account for a great invasion of the neighbouring houses by adult mosquitoes.

In several instances the waste-water drains were found silted up or blocked and numerous larvae were found in the pools so formed. In one instance where the drain was very long, the water had become purified to a certain extent, and Anophelines were breeding in it. Some of these drains have no proper outfalls, and form swamps at their terminations. In these both Anopheline and Culicine mosquitoes were breeding profusely.

(*g*) *Rain Water.*

The average annual rainfall in Rajkot is about 24 inches. On account of the dryness of the season in April, no observations could be made about the formation of breeding-places in the rains. It is probable that pools are formed in many places during the monsoon, more especially in hollows, excavations, borrow-pits, badly graded drains, 'pukka' tanks, etc. Such accumulations of water would act as dangerous breeding-places.

(2) Adult Mosquitoes.

On account of the dryness of the season, the number of adult mosquitoes captured were fewer than one would expect to get in the wetter weather. In the bungalows of the Civil Station adult mosquitoes are numerous in the evenings. The mosquitoes seemed to be chiefly Culicines, most probably bred in the immediate vicinity.

In the Followers' Quarters of the West Hospital, specimens of *A. stephensi, A. culicifacies, A. listonii, A. subpictus* and *C. fatigans* were collected. Large numbers of adult mosquitoes of the following species were captured in the Police Lines :—*A. stephensi*, *A. culicifacies*, *A. listonii*, *A. turkhudi* and *C. fatigans*.

A number of the Anophelines were dissected, but none were found infected with malaria parasites.

C. Incidence of Malaria in Rajkot.

Figures showing the attendances for 'fever' and malaria at hospitals in the Civil Station and the City have been kindly supplied to me by Major J. B. Hance, O.B.E., I.M.S., Agency Surgeon, W. I. S. Agency, and by Dr. N. K. Bam, Chief Medical Officer, Rajkot State (*vide* Appendix III). From these it would appear that, although a very slight rise may occur in March and April, the months of September, October and November are those in which 'fever' is most prevalent. One would expect the fever incidence to rise during these months, as this is the wettest time of the year. Pools formed by rain water are most abundant then, affording excellent facilities for the breeding of mosquitoes.

The local medical authorities state that the intensity of malaria in Rajkot is not equally distributed throughout the area. In the case of the Civil Station it is reported to be most prevalent in the neighbourhood of the Police Lines, the Jail and the West Hospital. From the distribution of the breeding-grounds recorded above, one would expect this to be the case.

As a measure of the endemicity of malaria the spleen and parasite indices have been studied.

(1) *Spleen Index.*

Through the kindness of Dr. A. P. Mehta, a splenic examination of 269 children, attending the Taluka Gujarati School in the Civil Station, was made in January 1929. The results recorded by him were as follows :—Seventeen children, or 7·6 per cent, showed some degree of splenic enlargement ; of these boys, 10 had spleens enlarged one finger-breadth beyond the costal margin, 3 had two finger-breadths and 4 had four finger-breadths of enlargement.

Dr. N. K. Bam has kindly given me the results of the examination of 135 children in Rajkot City, made during March 1929. Of these children twenty-four, or 17·7 per cent, had enlarged spleens ; 12 having one finger-breadth enlargement. 7 two finger-breadths and 5 three finger-breadths.

From these figures it is seen that of the 404 children examined the average spleen rate was only about 10 per cent. These figures, as compared with the findings in other parts of India, would place Rajkot among the 'healthy areas' or 'areas of moderate endemicity,' as far as malaria is concerned. The average spleen recorded in these children was only 0·17 finger-breadth and the average enlarged spleen 1·7 finger-breadth.

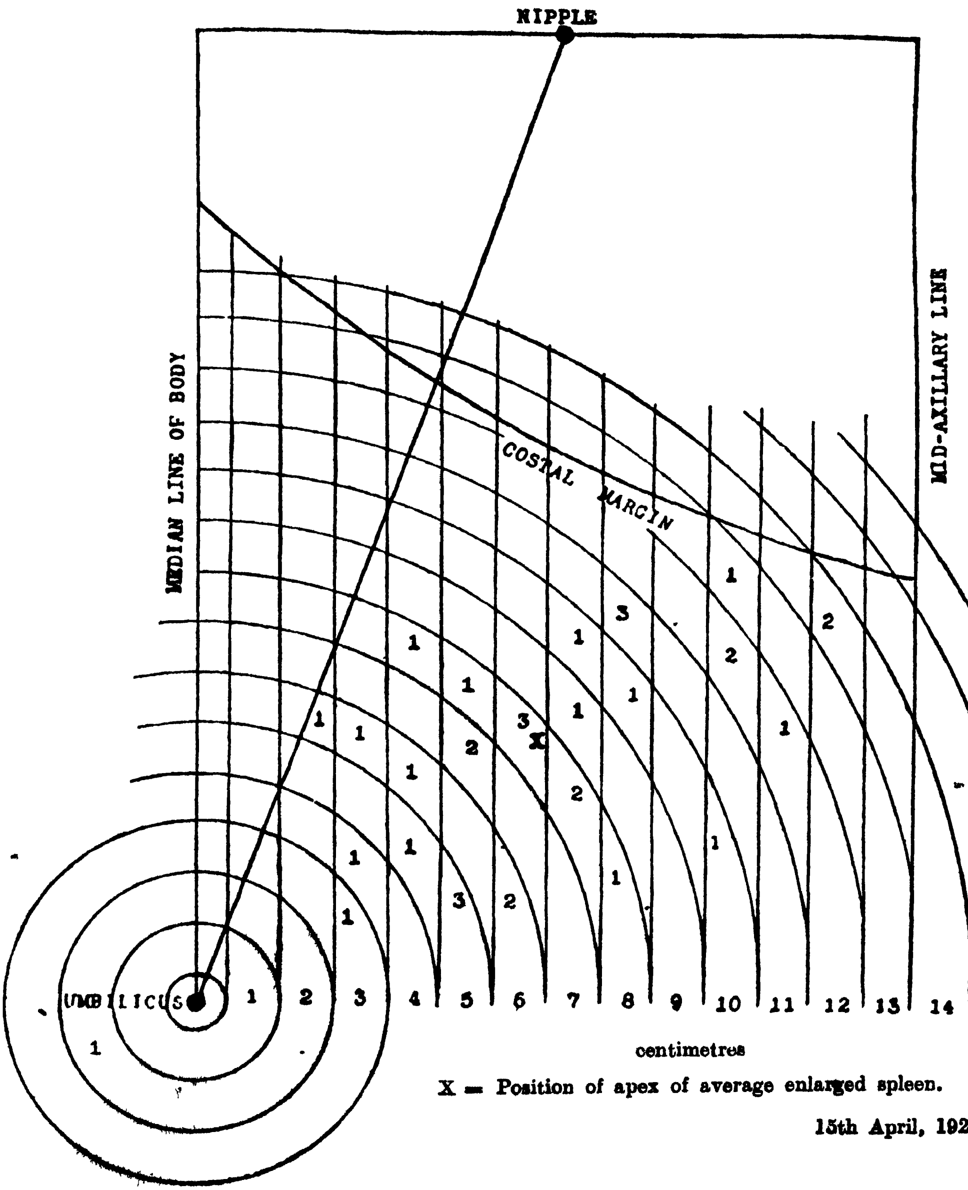
Fallacies are, however, present in the figures quoted Among children of school age there are few between the ages of 2 and 5 years, so the population is a selected one. It is also selected, because in many schools children of a low social status are not admitted, and the malarial prevalence among these is often much higher than that found in the rest of the population. More accurate results are obtained if children of all ages between 2 and 10 years and of all social classes are examined. It must also be remembered that these records were not taken at the most malarious

Chart I.

Results of Splenic and Blood Examinations at Rajkot.

Bloods examined	.. 53
Positive findings :	
P. falciparum	16
P. vivax ..	1
Mixed ..	1
Total positive	18
Parasite index	.. 34 per cent.

Children examined	..	53
Enlarged spleens	..	35
Splenic index ..	..	66 per cent.
Measurements av. enl. spleen :		
Apex-umbilious	..	7·9 cms.
Apex-midline ..	..	6 3 cms.
Total children showing evidence of malaria ..	..	39 or 74 per cent.
Number with crescents	..	5 or 9 per cent.



X = Position of apex of average enlarged spleen.

15th April, 1929.

season of the year, and that during the malarious months the spleen rate would probably be much higher.

The splenic indices in different parts of an area may vary with the physical features affecting the breeding of mosquitoes. Such indices may, therefore, give valuable indications of the local intensity of malaria in various parts of an area. To obtain such information, splenic examinations were made of children in the Police Lines and at the West Hospital. These were the regions indicated by local experience as being the most malarious. They were also those in closest proximity to extensive breeding-grounds of dangerous malaria-carrying Anophelines.

Police Lines.—Of 22 children residing in quarters about 200 yards from the river pools, thirteen, or 59 per cent, were found to have enlarged spleens, while of 14 children living on the bank of Nullah C, eleven, or 78·5 per cent, had splenic enlargement. The splenic index for the total 36 children was, therefore, 66 per cent.

Followers Lines, West Hospital.—Seventeen children, residing within about 100 yards of extensive breeding-places in the river bed, were found to have a spleen rate of 65 per cent.

Summary.—The total number of children examined in both places was 53 and the average spleen rate was found to be about 66 per cent, the average spleen being 1·5 finger-breadth and the average enlarged spleen about 3 finger-breadths.*

The low spleen rate, found among the school children from different parts of the area, would indicate that on an average the malarial incidence is not very high. The high spleen rate, however, found in the neighbourhood of extensive Anopheline breeding-grounds, shows that, combined with this general low spleen rate, there are areas of hyperendemicity related to certain special physical features of the ground. These results support the local opinion as to the distribution of the prevalence of malaria. The figures, though few in number, suggest that the nearer any population is to these extensive breeding-grounds, the greater the incidence of malaria among them.

(2) *Parasite Index.*

The bloods of 53 children were examined for malarial parasites, and of these sixteen, or 30 per cent, showed infections with *P. falciparum*, one, or 2 per cent., with *P. vivax*, and one was a mixed infection with both parasites. The parasite rate was, therefore, 34 per cent. Five, or 14 per cent, of the parasite carriers had crescents in their blood, i.e., were capable of infecting mosquitoes. Four of the children showing parasites in their blood had no detectable splenic enlargement.

It is a curious fact that no parasites were found in the bloods of children in the West Hospital Quarters, the parasite index in the Police Lines was, therefore,

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* The average degrees of splenic enlargement have been given as finger-breadths for comparison with the results recorded with the school children. The results of my examinations have been plotted on a standard abdominal chart (Chart I), from which it is seen that the apex of the average enlarged spleen is 6·3 cms. from the middle line and 7·9 cms. from the umbilicus.

50 per cent, which is very high. Possibly the greater facilities for treatment of attacks of the disease at the Hospital may have helped to account for these findings.

From these results it is seen that evidence of malaria, obtained either by blood or splenic examination, was found in 39 children, or 74 per cent. This indicates a high incidence of malaria in the areas examined.

D. Discussion of the Results of the Survey.

The results of the survey may be divided into (*a*) those connected with the mosquito nuisance, and (*b*) those connected with the incidence of malaria.

(*a*) *The Mosquito Nuisance.*

Towards the centre of the City any mosquito nuisance would appear to arise from accumulations of waste water in the vicinity of dwellings, and also partly from disused wells; while in areas in the proximity ot the river and the nullahs, the nuisance is greatly increased by mosquitoes derived from the multitudinous breeding-grounds in the beds of these watercourses.

In the residential portions of the Civil Station, mosquitoes are breeding extensively in waste-water sumps, tanks for water storage, blocked soak-pits, etc. The close proximity of these breeding-places accounts for the numbers of mosquitoes which invade the houses in the neighbourhood. The nuisance is probably increased during the rains by stagnant, undrained pools in the compounds and their vicinity. The disused wells contribute to the nuisance, but to a less extent than the places mentioned.

(*b*) *Malaria.*

The results of the investigations recorded above go to show that, while on an average, malaria is not very prevalent all over the area, yet it is very intense in certain places. These places are in close proximity to the river and nullahs, which may be considered to be the main natural breeding-places of Anophelines in this locality.

The malaria in areas situated at some distance from these natural watercourses apparently owes its origin to Anophelines hatched from artificial breeding-places, such as disused wells, tanks for water storage, etc. The large number of such places scattered over the area makes them an important factor in the spread of malaria.

It is also probable that during the wet season and immediately afterwards, the natural breeding-places are augmented by accumulations of water, swamps, and seepage in areas which are imperfectly drained.

E. Remedial Measures Suggested.

The remedial measures suggested may be divided into (1) anti-mosquito measures, and (2) anti-malarial measures.

(1) Anti-mosquito Measures.

These measures are directed against both Anopheline and Culicine mosquitoes. Such insects are most easily destroyed in their larval forms so measures for the abolition of surplus water, for rendering collections of water unsuitable for larvae, and for destroying these forms are indicated. While such measures may be carried out along the ordinary routine lines of anti-larval measures,* special recommendations are necessary in respect of the more important breeding-places.

(*a*) *Nullahs.*—The portions of these channels which contain water are the principal breeding-places in the areas in which they flow. It is recommended that a central drain be cut down the middle of each of these nullahs to collect the water into one main channel, instead of allowing it to wander all over the nullah bed as at present. This central channel should be as straight as possible, should have clean-cut, grass-free edges, and should be suitably graded to prevent the formation of swamps and stagnant pools. All the present swamps, pools, etc., in the nullah beds should be abolished either by filling them or draining them into the new central channel. Waste-water drains entering the nullahs should be connected with the central drain. This drain and all collections of water should be treated with oil once weekly.

The works recommended above are only temporary measures, but should be carried out before any permanent works are undertaken. When such a channel has been made, it will then be possible to estimate the size, depth and gradient of the permanent drains needed to deal with the amount of water flowing in the nullah at different seasons of the year. It will also reduce the number of breeding-places to a very large extent, so that anti-larval measures by means of oiling will be greatly facilitated and made more effective.†

It is, however, strongly recommended that permanent measures be taken to deal with these nullahs. For this it is suggested that those portions in which there is a permanent flow should be made 'pukka.' This would probably be done best by converting these parts of the nullahs into large drains, with stone-pitched sides and a central brick or cement cunette of sufficient size to carry the perennial dry-weather flow. In the case of those nullahs bordering upon the City, such drains seem necessary not only from the point of view of malaria and the mosquito nuisance, but also as a proper sanitary means of carrying away waste-water sullage, sewage, etc.

The swamps and pools formed at the entrance of the main nullah into the river bed at the Road Bridge should be abolished. The temporary central drain from the nullah bed should be carried down to the main stream of the river by a short channel.

* These are described in detail in 'Anti-mosquito Measures, with Special Reference to India' by Major G. Covell, I.M.S., in the Govt. of India Health Bulletin No. 11 (Malaria Bureau No. 3), published by the Govt. of India, Central Publication Branch, Calcutta, 1930.

† While the use of paris green as a larvicide would probably be a very effective and practical method of reducing the number of Anopheline larvae in these nullahs, it would not destroy the Culicines. Many parts of these nullahs form enormous nurseries of the latter kind of mosquito, so oil seems to be the larvicide of choice.

This will probably require to be made by blasting through the rocks of the river bed. All the old swamps and pools formed by the outfall of this nullah should be filled or drained to dry them up. When this has been done the 'pukka' channel of the nullah should be continued to join the main stream of the river.

In the portion of the nullahs which have not a perennial flow, the bed should be regraded. to prevent the formation of pools at the time of the monsoon and afterwards. Any pools left should be drained or filled if possible. Such as cannot be dealt with in this manner should be kept free of vegetation and oiled once weekly.

(*b*) *The River Bed.*—This presents a difficult problem and the breeding of mosquitoes seems to take place mainly in areas other than the main stream. It is recommended that the river be regulated, as far as possible, into one straight main stream in as narrow a channel as possible and should not be allowed to wander about, as at present, to form swamps, stagnant pools, etc.

These swamps and pools should be drained into this main stream, or better still, be filled in where possible. All drains entering the river should be carried as far as the main stream, and not allowed to form stagnant pools on the river bed, as at present.

Until this permanent work can be carried out, it is recommended that draining and filling of these areas should be started at once. Pools, etc., not drained or filled should be freed from vegetation and oiled weekly.* After the rains all pools and swamps in the river bed should be drained or filled where possible, and where this is impossible, they should be oiled weekly until the water in them has dried up.

(*c*) *Water Supply.*—All disused wells should be filled in, or else properly covered in such a manner that mosquitoes are not admitted. At present the wells, which are supposed to be covered, have broken tops and the manholes are all open. If certain wells must be kept in use, it is recommended that these be properly covered and pumps installed in them. If this is not feasible they should be treated with petrol once weekly.

Such disused wells as cannot be covered or filled should be kept free of vegetation and floating débris, and oiled once weekly. An experiment might be tried in the large well in the Residency Garden, as to the efficacy of fish in destroying mosquito larvae in wells in this area. If this well is kept free of floating vegetation and stocked with some of the small fish from the river, it might be possible to keep it free from larvae. Observations should be made in the matter. If this is successful, the stocking of some of the other large wells in the area might be tried, instead of oiling, but it must be remembered that fish may die out and the wells require restocking periodically.†

* From the point of view of malaria prevention, large sections of the river bed could be effectively dealt with by skilful dusting with paris green twice weekly, but unfortunately this would not abolish the mosquito nuisance due to Culicines.

† In the summer of 1930, numbers of *Gambusia* were available at the Ross Field Experimental Station for Malaria, Karnal, and some of these have been sent to Rajkot for trial as to their value in wells, etc.

It is recommended that a census be made of the wells in the area and that these be numbered and their position marked on a map. This will facilitate the inspection of such wells and ensure that none are accidentally overlooked during the course of anti-larval operations.

Proper drainage should be installed to carry off waste water from taps, wells, etc.

(*d*) *Water Storage.*—The wire gauze covering the manholes of the stone reservoirs is of too large a mesh. It is recommended that a mesh of, at least, 16 strands to the inch be used, and that the manholes be either screwed down or properly locked.

Water-storage sumps should be oiled weekly, or else emptied and left dry for two consecutive days weekly. Ornamental fountains and ponds should be kept free of vegetation of all sorts and oiled once weekly. Alternatively these may be stocked with fish, if the experiment in the Residency well is successful, or else emptied like the water-storage sumps.

Storage tanks and sumps in unoccupied bungalows should be emptied or oiled. These require special attention during the rains.

(*e*) *Waste Water.*—It is from waste water that a great amount of the mosquito nuisance in the residential area arises. The blocking of waste-water drains, the swamps formed at their terminations, neglected soak-pits, etc., are the main breeding-places. Sumps for waste water should be oiled once weekly. Waste-water drains should be kept clean and water not allowed to stagnate in them ; a weekly washing of such drains with cresol or phenyle is advised. The drains should not be allowed to form swamps at their terminations. If they cannot be connected with proper drainage channels, the water might be disposed of in soak-pits which must however be properly looked after. All soak-pits should be oiled once weekly.

(*f*) *Irrigation Water.*—Over-irrigation resulting in the formation of stagnant pools should be avoided. Pools and swamps formed by seepage from irrigation channels should be filled or drained.

(*g*) *Rain Water.*—The drains for the disposal of storm water should be cleared out and regraded, where necessary, to prevent the stagnation of water in them. At the time of the rains a survey should be made of the whole area to detect all places where such stagnation is taking place. Arrangements should be made to fill or drain all low-lying areas where water collects.

(*h*) *Miscellaneous.*—The execution of the work on the river bed, nullahs, wells, etc., will require a considerable amount of major engineering work, but most of the other recommendations can be carried out by householders. I do not know whether occupiers or landlords of bungalows can be compelled to keep their premises free from mosquitoes, but it is suggested that a publicity campaign should be started with this object in view. If this fails perhaps some action might be possible under the Section of the Cantonment Act which deals with nuisances on premises.

I would also recommend that a whole-time Malaria Officer should be appointed for the area, with a gang of coolies under him. This officer would be employed in doing weekly inspections of the area and superintending the anti-malarial

measures being carried out. He could also give demonstrations to the residents as to the best methods of keeping their compounds free of the breeding-places of mosquitoes.

(2) Anti-malarial Measures.

The ordinary measures of personal prophylaxis should be carried out,* more especially in those localities which have been shown to have a high incidence of the disease.

All persons suffering from malaria should be given proper courses of treatment. By this means the numbers of carriers of the disease would be reduced. In the case of quarters, houses, etc., in the more malarious portions of the area, it is recommended that the children living there should have their spleens and bloods examined once every three months and all cases of malaria detected at these examinations be given a proper course of treatment. The cheap or free distribution of quinine or cinchona febrifuge in such districts would probably reduce not only the severity of the disease but also its incidence.

Part II.

REPORT ON A SHORT MALARIA SURVEY AT JUNAGADH CITY.

A short investigation into the prevalence of malaria and mosquitoes was made at Junagadh between 17th and 21st April, 1929. The brevity of the visit and the fact that it was made at the dry season of the year necessarily make the results very incomplete.

A. Topography, etc.

Junagadh City is the chief town of Junagadh State in Kathiawar. Its geographical position is 20° 31′ N. and 70° 36′ E. The population of the City is about 40,000. The average rainfall is about 34 inches per annum. The mean minimum temperature is 58°F in January, and the mean maximum 105°F. in May.

The City is situated on a hill at the foot of the Girnar Range and is surrounded by a wall. The suburbs are mainly on the plain to the south and west of the City. The bulk of the population of the City is crowded into the southern and western portions of the walled area, while in other parts the population is comparatively scanty and scattered. The suburbs are mainly occupied by the palaces, official residences, bungalows and large gardens. The population of this area is small as compared with that of the City proper and is scattered.

The main sources of water may be classified as follows :—

(1) Nullahs ; (2) Water supply ; (3) Water storage ; (4) Irrigation ; (5) Waste water ; and (6) Rain water.

(1) *Nullahs.*

There are three main nullahs in the area under survey, namely the Kalva Nullah, the Triveni Nullah and the Damarkund Nullah, with their tributaries. At

* Details of these are given in 'Anti-mosquito Measures, with Special Reference to India' by Covell (1930) (*vide* Footnote on p. 361).

the time of the survey large portions of these nullahs were dry, but in the regions towards the foot of the Girnar Hill, some of them showed stagnant pools of water and flowing streams. It is probable that, during and after the monsoon, all these nullahs contain water along the greater portion of their course, and afford suitable places for the breeding of mosquitoes.

(*a*) *The Kalva Nullah.*—This nullah runs along the eastern side of the suburbs until it reaches the vicinity of the City, where it turns westward parallel with the City wall. At the time of the visit, there was only a dry rocky bed present in the neighbourhood of the City. It was evident, however, that during the wetter seasons of the year many places suitable for the breeding of dangerous mosquitoes would appear in this stream. Opposite the middle of the southern wall of the City, a large branch is given off to supply water to the Khokharia Talav, a large tank. In April this nullah was probably only breeding mosquitoes in its upper reaches, towards the back of the Lancer Lines.

(*b*) *The Triveni Nullah* - This flows along the north-eastern part of the City wall. It was found to be full of stagnant pools, many of which were filled with grass and vegetation, and were breeding dangerous Anopheline mosquitoes. Fortunately this nullah is at a considerable distance from the populous portions of the area. The conditions, however, may be taken as an indication of what may be expected in the dry portions of other nullahs after the rains.

(*c*) *The Damarkund Nullah.*—The portion of this nullah along the road towards the Girnar Hill seems to have a perennial stream. It contains many pools with grassy edges and with much water-vegetation, forming ideal breeding-places for mosquitoes, the larvae of which were found to be present in considerable numbers. Although at a considerable distance from the City, this nullah has many temples and rest-houses for pilgrims along its banks.

(2) *Water Supply*

There is a piped water-supply to this area but wells are still used to a considerable extent. The depth of these wells varies very much according to their position on the hill. Those near the top of the hill may be 100 feet or more in depth, while the water in those near the plain is only about 20 feet from the surface. The majority of these wells are of large size, and are cut into the solid rock.

The wells which were in constant use did not seem to be breeding mosquitoes in any large number in April. They should be examined at other times of the year to confirm this. The disused wells were in a number of instances acting as breeding-places for mosquitoes, and all wells should be considered as potential sources of these insects.

(3) *Water Storage.*

Three large tanks for the storage of water were examined in the suburbs. Of these the Dattar Tank has earthen banks and the water margins showed many isolated pools and considerable aquatic vegetation, in which prolific breeding of mosquitoes was going on. The Khokharia Talav, another earthen tank, was almost

empty when examined, but in the filthy pools of stagnant water remaining the larvae of Anopheline mosquitoes were found. The Peri Tank is built of masonry, and contains large numbers of small fish with little or no aquatic vegetation. As a result, no larvae were found in the tank itself, although they were present in some of the smaller 'pukka' tanks and channels on its bank.

Many of the palaces and bungalows have fountains, small masonry tanks for water storage, etc., and these were found to be breeding in some instances. Such places must always be looked upon as dangerous potential breeding-places for Anopheline mosquitoes, more especially the malaria-carrying species.

(4) *Irrigation.*

The gardens of private residences are mainly irrigated by the piped water-supply. As the water did not appear to be used in excessive amounts, the actual irrigation was not found to be causing mosquito breeding. However, in many instances there were pools of stagnant water at the bases of their irrigation standards, which is undesirable.

The large gardens to the south of the City are irrigated from wells which, because of their constant use, did not seem to be breeding mosquitoes. The chief danger to be anticipated in this area would arise from allowing the irrigation channels to become grass-grown, and permitting breaches or seepage from these channels to form pools in the vicinity.

(5) *Waste Water.*

In many places no provision is made for the disposal of waste water from stand-pipes or wells, with the result that stagnant pools are formed. In some bungalows the waste water from the kitchens and bath rooms is collected into sumps, which in many instances are breeding mosquitoes prolifically.

At present there is no proper drainage system for the disposal of waste water from very large portions of the area. Where 'pukka' drains are present, these are often blocked, forming stagnant pools. Many of these drains discharge into earthen channels and terminate in swamps near habitations, with the result that much mosquito breeding is taking place in them.

I understand that it is proposed to install a proper drainage system which should do much, if properly constructed, to alleviate the plague of domestic mosquitoes.

(6) *Rain Water.*

The average annual rainfall is about 34 inches. The hill on which the City is built has been quarried very extensively from time immemorial. The result is that both inside and outside the City there are large excavations. Many of these must become filled with rain water during the monsoon and form mosquito-breeding pools. Fortunately the majority of these are at some distance from the more populous areas. In many localities there are also numbers of smaller borrow-pits, which may act in a similar manner during the rains.

In the City proper, the hilly nature of the ground should allow storm water to drain off rapidly, and prevent the formation of stagnant pools, except in the case of excavations similar to those mentioned. In the suburbs, on the other hand, the flat nature of the ground makes the disposal of such water more difficult. There are numerous dry storm-water nullahs more especially those running down on either side of the Sardar Bagh, which are in many instances shallow and overgrown with vegetation. These must have many pools and swamps along their courses during the rains. Numerous pools will also be formed and left in the beds of the three main nullahs mentioned above. The overflow and seepage from the Khokharia Talav will also help to form mosquito-breeding places.

B. The Mosquitoes of Junagadh.

From the point of view of the sanitarian, the mosquitoes of any area are important both as carriers of disease and because of the nuisance which their bites may cause. Of the diseases carried by these insects the most important is the carriage of malaria by members of the genus *Anopheles*. The following species of Anopheline mosquitoes were found at Junagadh :—*A. stephensi*, *A. culicifacies* and *A. subpictus*, of which the first two are dangerous carriers of malaria. It is probable that a more prolonged survey, especially after the rains, would reveal several other species of this genus.

Apart from the possible carriage of such other diseases as filariasis, dengue and similar fevers by mosquitoes, these insects are a pest in some parts of Junagadh at certain times of the year. The Culicine mosquitoes identified from here were : *Culex fatigans*, *C. vishnui*, *C. bitaeniorhynchus* and *Lutzia fuscana*.

(1) Breeding-places of Mosquitoes.

In Appendix IV are given records of some of the breeding-places found at Junagadh. These only represent a sample of the type found, and should give a good idea of what may be expected in other parts of the area where similar conditions prevail at any time of the year. The number of such breeding-places is probably much increased during the monsoon and afterwards.

(a) *Breeding-places in Nullahs.*

The portions of the Triveni and Damarkund Nullahs may be taken as examples of what may be expected in these streams in any place where water is present. It will be seen that the two dangerous malaria carriers, *A. culicifacies* and *A. stephensi*, have been found in considerable numbers in these places. This indicates that these nullahs, if not attended to, may be the cause of serious outbreaks of malaria among persons living in their vicinity.

(b) *Breeding-places in Relation to Water Supplies.*

The main breeding-places in this connection are due to leakage around water taps and to wells. Disused wells were found to be breeding both Anopheline and

Culicine mosquitoes. Wells are a very favourite breeding-place of *A. stephensi*, which is probably mainly responsible for the transmission of malaria in the City proper.

(c) *Breeding-places in Relation to Water Storage.*

The clean water of storage tanks, which are present in considerable numbers, affords a very suitable place for the breeding of Anopheline mosquitoes, more especially *A. stephensi*. If any vegetation is present in them, *A. culicifacies* may also occur.

The large tanks with earthen edges, more especially when vegetation is present, have been found to breed *A. culicifacies*, *A. stephensi* and *A. subpictus*, as well as *C. fatigans*, *C. vishnui* and *C. bitaeniorhynchus*. The hoof-marks of cattle in the soft margins of these tanks, in some instances, contained water full of larvae.

'Pukka' tanks like the Peri Talav, which have no vegetation and many fish, were found to be free of mosquito larvae. The irrigation channels on their margins contained them. During the period when the Khokharia Talav is full of water, the occurrence of seepage pools along the base of its embankments should be looked for. Such pools and swamps are very favourite places for mosquito breeding.

(d) *Breeding-places in Relation to Irrigation.*

The large wells used for irrigation did not seem to be breeding mosquitoes. Suitable breeding-places are found around the bases of water pipes for irrigating gardens and in cement tanks beside wells. Leakage from irrigation channels occurring during the rains should be searched for and remedied.

(e) *Breeding-places in Relation to Waste Water.*

Waste water spilled around stand-pipes, wells, watering troughs, etc., is a fruitful source of mosquitoes, though these are mostly of species which do not transmit malaria. Larvae were also present in large numbers in blocked and grass-grown drains. As these drains are close to dwellings, the adults must give rise to a considerable nuisance. Some of these drains discharge into 'kutcha' nullahs or swamps and thus form numerous breeding-places.

(f) *Breeding-places in connection with Rain Water.*

As April is one of the driest months of the year, it was impossible to give any account of the effect of heavy rain on the formation of breeding-places. It was evident, however, that pools probably form in many quarries in the vicinity, as well as in borrow-pits. No proper drainage arrangements are apparent for the disposal of storm water from the flatter areas outside the City. It appears to run away in broad, shallow, natural nullahs in some instances, and these seem likely to form swamps and pools after rain. The extent to which rain water forms breeding-places should be investigated at the end of the rainy season.

(2) Adult Mosquitoes.

In some places these were found to be very numerous, but in most areas they were rare at this dry season of the year. The mosquitoes captured were chiefly *C. fatigans*, but specimens of *A. culicifacies* and *A. subpictus* were also caught. It was evident from the number of larvae found, chiefly in waste water, that these insects must form an intolerable nuisance in some areas. It seems probable that after rain, when many stagnant pools are formed, an abundance of mosquitoes must be present, especially in the suburbs. These would be both Anophelines and Culicines.

C. Incidence of Malaria in Junagadh.

There seem to be no published reports on the incidence of malaria in Junagadh. Figures giving the attendances for malaria at the Junagadh Dispensary during the last three years have kindly been supplied to me by Captain Mazumdar, Chief Medical Officer, Junagadh State (*vide* Appendix V). From these figures it will be seen that malaria is most prevalent during the latter half of the year, although there is a slight rise about April. One would expect the malarial incidence to rise in the autumn, as this is the end of the rainy season. The formation of rain-water collections, combined with the presence of water in the nullahs near the area, would afford great facilities at this time for an increase in the breeding-places of mosquitoes, more especially those which carry malaria. The recorded deaths from 'ague' during the last 10 years are shown in Appendix VI.

During the visit an attempt was made to determine the degree of malarial endemicity in this area by means of records of the splenic and parasite indices.

(1) *Splenic Index.*

Captain Mazumdar has kindly supplied me with the results of a splenic census made during March 1929 among children of the age of 10 years or less attending ten schools in Junagadh City (*vide* Appendix VII). A total of 2,242 children were examined and among these the splenic index was found to vary between 1·25 and 17 per cent, with an average of 7·27. Eight of these schools, comprising over 1,700 children, had a rate of 10 per cent or less. It is of interest that the average spleen rate in the girls' schools is only half that of the boys' schools.

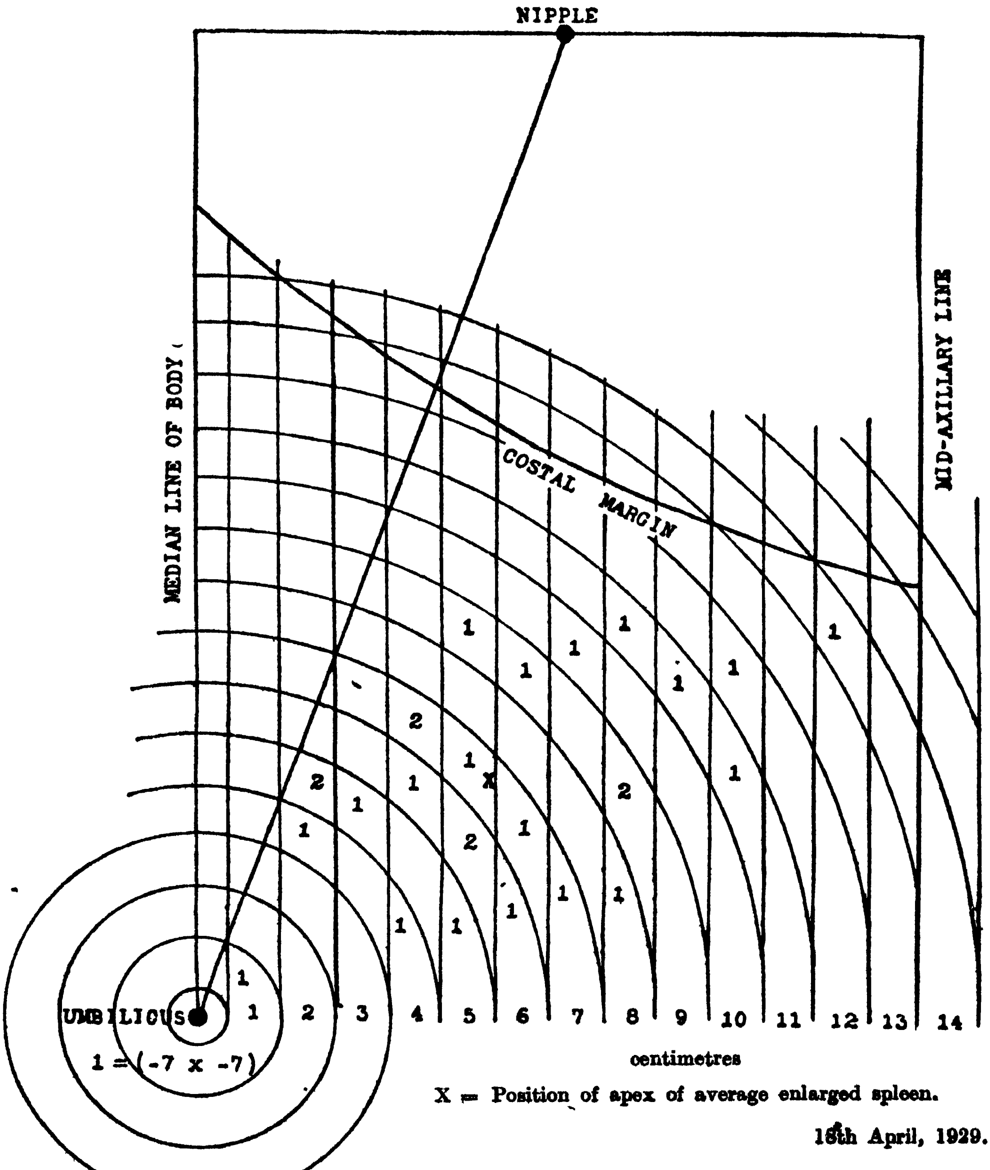
From these figures it would seem that the incidence of malaria at this, a comparatively healthy time of the year is on an average low. The index would probably be considerably higher during the wetter months of the year. Even taking this into account, one would have expected a considerably higher index in March, if malaria was a very prevalent disease all over the area. It must be remembered that school children are a selected population in which few children between the ages of 2 and 5 years are included, and also that the majority of the school children belong to the upper classes. This may be the reason why the index among the girls was lower than among the boys. If younger children and those of a lower social status were included, the index would probably be higher. Even this selection of children

Chart II.

Results of Splenic and Blood Examinations at Junagadh.

Bloods examined	56
Positive findings :	
P. falciparum	12
P. vivax	1
Mixed	1
Total positive	14
Parasite index	25 per cent.

Children examined	58
Enlarged spleens	29
Splenic index	50 per cent.
Measurements av. enl. spleen :	
Apex-umbilicus	7·0 cms.
Apex-midline	5·3 cms.
Total number of children with evidence of malaria	36 or 62 per cent.
Number with gametocytes	3 or 5·3 per cent.



X = Position of apex of average enlarged spleen.

18th April, 1929.

would not, in my opinion, account for the low splenic index, apart from an absence of general severe malarial incidence.

As a majority of the population is concentrated in a comparatively small area (the City), where there are few breeding-places for Anopheline mosquitoes, one would not expect to find a high average incidence of malaria there. To obtain some idea of the prevalence of malaria in places on the outskirts and beyond the area, where greater facilities for mosquito production are present, an examination of the children in the Lancer Lines was made.

Forty-six children were examined, and of these twenty-three, or 50 per cent, showed splenic enlargement, the size of the average enlarged spleen being 3 finger-breadths beyond the costal margin. The results are high, and point to a considerable incidence of malaria among these children.

Twelve children resident in the compound of the State Hospital were also examined by me, and a splenic index of 50 per cent was again found.

These results have been plotted on a standard abdominal chart (Chart II), from which it is seen that the position of the apex of the average enlarged spleen in these 58 children was 5·3 cm. from the mid-line and 7·0 cm. from the umbilicus.

These findings indicate that, although the average incidence of malaria over the area is low. yet in those places near which there are many facilities for Anopheline breeding, malaria is prevalent. The low incidence of malaria in the City proper, with a high incidence in the suburbs, is what one would expect from the results of the mosquito survey.

(2) *Parasite Index.*

Blood films from fifty-six of the children whose spleens were examined, were taken, and in fourteen of these or 25 per cent parasites were detected. In twelve cases the parasites found were *P. falciparum*, in one *P. vivax*, and in one a mixed infection with both parasites. Among these children two were found to be carriers of the gametocytes of *P. vivax* and one of *P. falciparum*. The percentage of carriers of parasites detected is high for this period of the year, and seven of these children showed no splenic enlargement. These results suggest that a certain amount of malaria infection was taking place at this time of the year. The figures given in Appendix V show a rise of the malarial incidence during March and April of the last two years, and would support such a view.

As the results of these investigations evidence of malaria was found in 36 children, or 62 per cent of those examined.

D. Discussion of the Results of the Survey.

The results of the survey may be divided into those connected with (*a*) the incidence of malaria. and (*b*) the mosquito nuisance.

(a) *Malaria.*

From the figures recorded above, it would seem that in the crowded portions of the City, the malarial incidence is low, but that in areas near the large breeding-places of mosquitoes the incidence is high. During the dry season the main breeding-places of dangerous mosquitoes appear to be water-storage tanks and wells. Dwellings near permanent breeding-places, such as the different nullahs, would also be expected to have much malaria.

During the wet season one would not expect much augmentation of the malarial incidence in the centre of the City. One would expect it, however, in places situated near quarries and similar depressions which collect rain water, and also in those near the nullahs, which would not then be dry as they were in April.

A high incidence of malaria is to be expected in the regions where permanent water is present in these nullahs. It is probable that many pilgrims lodging in the rest-houses along the Damarkund Nullah contract the disease there.

(b) *The Mosquito Nuisance.*

In the City proper the main mosquito nuisance appears to arise from accumulations of waste water and from disused wells. During the rains this nuisance is probably increased by breeding in borrow-pits, quarries, etc., situated within a few hundred yards of dwellings. It is probable that breeding in accumulations of waste water from drains and in pools of rain water, as well as in the Kalva Nullah, may add to the mosquito plague in dwellings near the peripheral zone of the City.

In the suburbs at the time of the visit, the main source of the mosquito nuisance was in waste-water accumulations, either in sumps or in drains. This nuisance was added to, but to a less extent, by mosquitoes from wells, water-storage tanks and spill-water from stand-pipes. The appearance of the ground suggests that in many areas during the rains, pools and swamps are formed in depressions in the ground, borrow-pits, quarries, storm-water channels and stream beds. Many mosquitoes would be expected to invade neighbouring houses from these breeding-places.

E. Remedial Measures Suggested.

(1) *Miscellaneous General Recommendations.*

It would be very advantageous if a special medical officer were appointed to deal with the supervision and execution of anti-malarial and anti-mosquito measures. This officer should have no other duties, except those in connection with the prevention of malaria. He should be provided with a proper staff of coolies, etc., for oiling, drainage, etc., as well as a supply of tools, larvicides, etc.

It must be remembered that mosquitoes may fly for considerable distances. Even if the occupier of a compound attempts to keep his own area free from mosquitoes, his results may be nullified to a considerable extent by the immigration of mosquitoes breeding in neglected compounds and land in the vicinity. It,

therefore, seems necessary that some steps should be taken to protect those persons who are taking measures to eradicate mosquitoes on their own property.

In the case of the residential area, it should be possible to enforce a regulation making the owner or occupier of any land or premises responsible that his area is kept free from mosquito-breeding. The anti-malaria officer would advise such persons as to the best manner in which they can accomplish this. The finding of larvae on any premises would be taken as proof that the regulation is not being carried out. Regulations of this kind are strictly enforced in the United States of America and in other countries.

A publicity campaign would probably aid matters, in directing and educating public opinion as to the dangers of malaria. It would also emphasize the need for co-operation by the people themselves in the abolition of mosquitoes and so of malaria. In many Bengal villages such co-operative campaigns have been instituted with considerable success.

(2) *The Nullahs.*

The streams in these nullahs should be straightened out and the water made to run, as far as possible, in one main channel, all side pools being obliterated. The streams should be kept free of aquatic vegetation, and the banks cleared of grass and jungle. The use of larvicides should be resorted to once a week or oftener in the portions of the stream near dwellings, giving special attention to stagnant pools, no matter how small. If the training of the stream is properly carried out, such pools should be few in number. The use of paris green as a larvicide twice weekly during the malaria season should abolish most of the Anophelines breeding in these streams. As this larvicide has little effect on Culicines, such a measure would not have much effect on the mosquito nuisance, and for this reason oiling once weekly would probably be a better measure.

(3) *Wells.*

All wells not in use for drinking purposes should be closed or filled in. If this is not possible, they should be oiled once weekly. Drinking-water wells should be properly covered to render them mosquito-proof and pumps installed. If certain wells must be kept uncovered they should be treated with petrol once weekly. As suggested for the wells at Rajkot, experiments might be tried with fish in these wells.

(4) *Large Water-storage Tanks.*

Tanks like the Dattar and the Khokharia should have their margins clean cut, so that shallow pools are not formed at their edges. It is advisable that special portions of the margins of these tanks should be set apart for the watering of animals and that these portions should be paved. The reason for this is that cattle are liable to cut up the soft edges, and form breeding-places for mosquitoes. The margins and surface should be kept free of aquatic vegetation and jungle. It would also be advisable to stock these tanks with fish from the Peri Talao. The margins of the tanks may require oiling once weekly.

(5) *Cement Tanks for Water Storage, Fountains, etc.*

Water-storage tanks should be emptied and completely dried on two consecutive days weekly, or else oiled once a week. The same procedure might be adopted for fountains, etc., but it would be worth while trying if these can be kept free of larvae by placing fish in them. All these tanks should be kept free of aquatic vegetation, which affords food and shelter for the larvae. These clean-water tanks form very suitable nurseries for dangerous Anopheline mosquitoes in the immediate vicinity of dwellings.

(6) *Waste-water Tanks.*

Such tanks should be oiled once weekly.

(7) *Waste-water Drains.*

These should be oiled or treated with cresol once weekly.

They should be kept clean and special attention given to swamps, pools, etc., formed beyond the 'pukka' portions of the drains. The question of regrading the drains, so that stagnant pools are not formed, should be considered in connection with the proposed new drainage scheme.

(8) *Quarries.*

Any of these situated within ½ mile of populous areas should be drained or filled to such a depth that rain water does not accumulate in them. In the case of quarries which are too deep to treat in this manner, oiling should be carried out weekly, so long as any water is present. The water surface should be kept free of aquatic vegetation. Borrow-pits and similar excavations should be dealt with in a like manner.

It is suggested that a regulation should be passed to prevent the formation of such quarries in future, unless they are made so as to permit proper drainage to prevent the accumulation of water in them.

(9) *Irrigation.*

Water-storage tanks in the vicinity of wells should be oiled weekly. Special attention should be given to keeping the irrigation channels free of all vegetation and in good repair. Over-irrigation and the formation of stagnant pools from leakage, seepage, etc., of the channels should be avoided.

(10) *Rain Water.*

Some proper system for the disposal of storm water should be installed. The extent of this could only be determined during the rainy season. If a 'pukka' system cannot be installed, the present natural drainage channels should be properly graded, deepened and narrowed. This should prevent the rain water from flowing away, as at present, in wide, shallow streams forming swamps. The storm water channels should be concentrated, as far as possible, instead of allowing

this water to spread over the country in numerous small channels. These channels, should be graded so as to prevent pool formation, and should be kept free of grass and jungle, both in their beds and along their banks. They should be given a proper outfall into one of the natural watercourses of the area, and not allowed to end in swamps.

If the storm water is properly controlled in the manner suggested, there should be little or no breeding in these drains while they are being flushed by storm water, but when the rains have ceased they will require oiling once weekly until they dry up.

(11) *Notes on Special Areas.*

(*a*) *The City.*—Attention to wells. Installation of proper drainage and avoidance of collections of waste and rain water. Drainage, filling and oiling of quarries near populous areas.

(*b*) *Bungalows and residences in the suburbs.*—Treatment of wells, fountains. ornamental and water-storage tanks. Attention to drains, waste-water sumps, washing tanks, etc. Filling, draining or oiling all adjacent hollows. quarries, or borrow-pits containing water.

(*c*) *Aman Mahal Palace.*– Attention to same points as for bungalows. Special work on levelling and draining the grounds, which are very broken and must contain many pools during the rains.

(*d*) *Datar Manzil.*– As for bungalows.

(*e*) *Mahabat Manzil.*—As for bungalows. A special watch to be kept on the swimming bath.

(*f*) *Sardar Bagh.*—As for bungalows. Attention to drainage system, waste-water sumps, water-storage tanks, ornamental water, etc. Special work to make proper storm-water drainage channels on both sides of this Bagh, for it is evident that during and after the rains this area is almost isolated by swamps and pools, which must breed many mosquitoes.

(*g*) *The Lancer Lines.* –Treatment of pools in the quarries behind the lines, and also the Kalva Nullah. Medicinal treatment of all children showing evidence of malaria. Issue of quinine twice weekly during the malarial season.

Part III.

REPORT ON A VISIT TO SASAN VILLAGE IN THE GIR FOREST.

Through the kindness of Major F. B. N. Tinley, M.C., Chief Secretary, Junagadh State, I was given the opportunity of visiting a village in this very malarious tract on 19th April, 1929.

The Gir Forest lies about 40 miles south of Junagadh City. It has for centuries been notorious for the prevalence and the deadliness of its malaria. Immigrants into this district suffer very severely from the disease. The sickness and mortality among the police and their families posted to this area is so great that they dread

being sent there. It is almost considered equivalent to a sentence of death on their families.

A. TOPOGRAPHY.

The village of Sasan is situated in the middle of the Gir Forest on high ground about 100 yards from the left bank of the Horon River. Its population is only about 100 to 150 persons. The rainfall is said to be about 100 inches per annum, that is, nearly 3 times that of Junagadh City.

The village lies on high ground cleared of forest and scrub, in the midst of country composed of small jungle-clad hills cut up by nullahs. These were dry at the time of the visit, but must contain streams and pools during the rains. The forest is the haunt of lions, leopards and other wild animals.

B. THE MOSQUITOES OF SASAN.

In front of the rest-house is a large cement tank for water. This was found to contain very numerous mosquito larvae which proved to be those of *A. subpictus* and Culicines.

The Horon River flows in a wide rocky bed immediately below the village. The stream has many pools in its bed, and these contain much aquatic vegetation. Large numbers of Anophelines were breeding in the river bed. The species found were *A. culicifacies*, *A. stephensi*, *A. turkhudi*, *A. pallidus* and *A. subpictus*. The two first species are notorious carriers of malaria. Numerous Culicine larvae were also present, and proved to be *C. fatigans*, *C. vishnui* and *C. bitaeniorhynchus*.

Some of the other streams in and on the edge of the forest were examined, and were found to contain the larvae of *A. culicifacies*, *A. stephensi*, *A. turkhudi*, *A. subpictus* and Culicines in profusion. The last were *C. fatigans* and *C. bitaeniorhynchus*.

Adult mosquitoes were caught with ease in the houses of the village. The species identified were *A. culicifacies*, *A. stephensi* and *A. turkhudi*, as well as *C. fatigans*.

From the presence of so many dangerous malaria-carrying mosquitoes, even at the driest time of the year, it is not to be wondered at that malaria is prevalent.

C. THE INCIDENCE OF MALARIA.

As mentioned previously, the Gir Forest is notorious for its very virulent and deadly malaria. In Sasan the sickness and mortality due to the disease is said to be very great.

(1) *Splenic Index.*

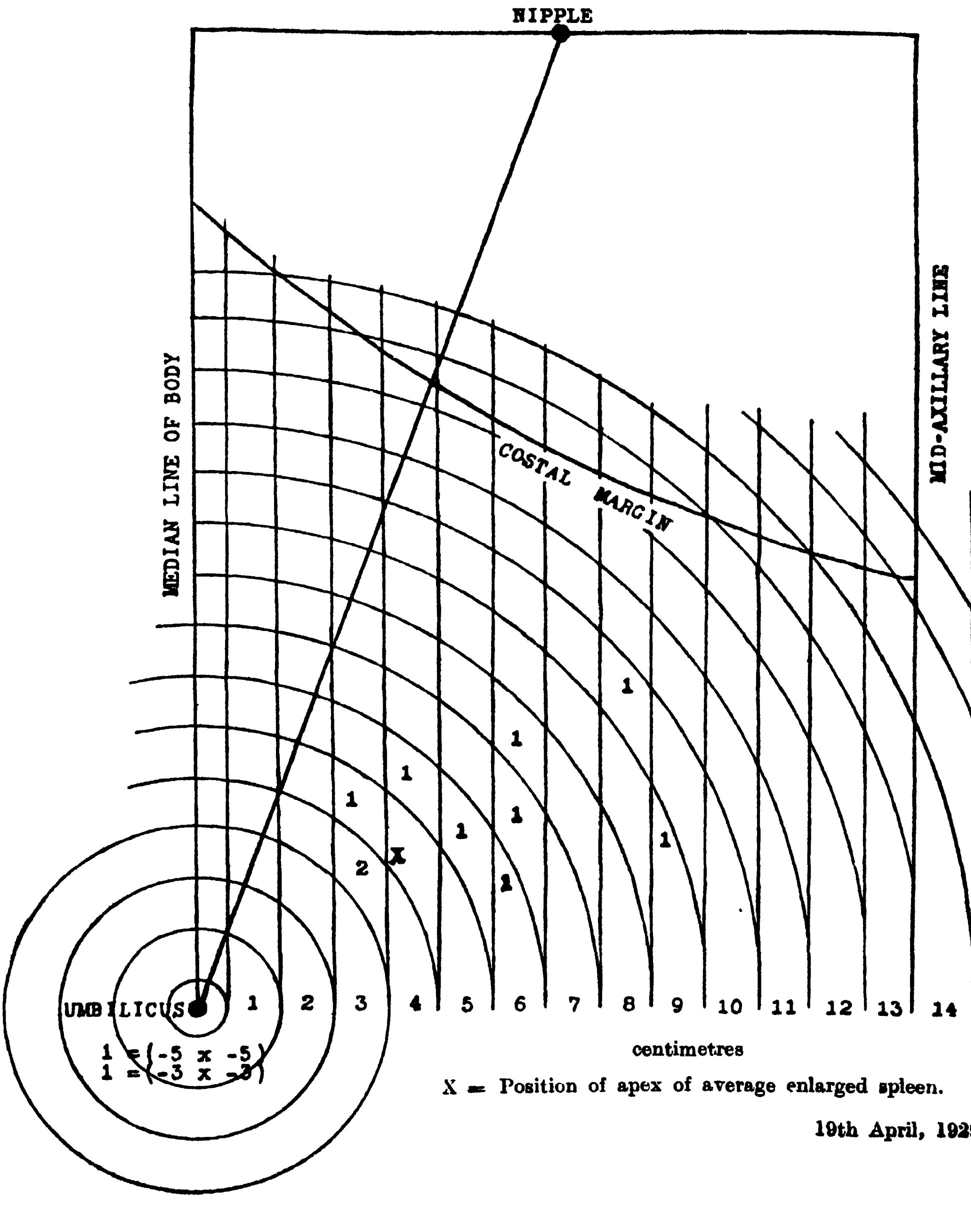
Twelve children between the ages of 2 and 10 years were collected and all these showed splenic enlargement. Of two other children examined who were less than one year old, one had also an enlarged spleen. The average size of the spleen was 4 finger-breadths beyond the costal margin.

The results of the examination have been shown in detail in Chart III. The position of the apex of the average enlarged spleen was 4·6 cm. from the umbilicus

Chart III.

Results of Splenic and Blood Examinations at Sasan, Gir Forest.

Bloods examined	.. 12	Children examined ..	12
Positive findings :		Enlarged spleens ..	12
P. falciparum	4	Splenic index	100 per cent.
P. vivax ..	3	Measurements av. enl. spleen :	
Mixed ..	1	Apex-umbilicus ..	4·6 cms.
P. malariae	1	Apex-midline	3·7 cms.
Total positive	9	Total number of children with evidence of malaria	12 or 100 per cent.
Parasite index	.. 75 per cent.	Number with gametocytes	2 or 16 per cent.



X = Position of apex of average enlarged spleen.

19th April, 1929.

and 3·7 cm. from the middle line. It will be noticed that two of the spleens extended markedly beyond the umbilicus, while the smallest spleen was at least two finger-breadths beyond the costal margin. These findings point to a very high degree of endemicity of malaria.

(2) *Parasite Index.*

In nine, or 65 per cent, of the 14 children examined, parasites were found in the peripheral blood. In four cases the parasites were *P. falciparum*. in three *P. vivax*, in one *P. malariae* and in one a mixed infection of the two first species. Three cases were gametocyte carriers.

The figures of the splenic and parasite rates are very high and show that practically every child in the village has malaria. This is a condition which is only found in the most malarious parts of the world, and such a high splenic index is very rare. These findings confirm the local opinions on the high prevalence of malaria in the Gir Forest.

D. Anti-malarial Recommendations.

The smallness of the population at Sasan makes it very doubtful whether it would be possible to abolish the mosquito-breeding at a reasonable cost. If the stream was trained as recommended for the nullahs at Junagadh, it should be possible to reduce the breeding of mosquitoes very considerably. This might be done in conjunction with the use of paris green.

Probably the best solution of the malaria problem, as far as the village is concerned, would be to remove it to a less malarious site. Whether such a site can be found in the immediate vicinity would require further investigation, to be undertaken at a more malarious season of the year.

(*a*) *The Rest-House.*—As this is used by many high officials, it is strongly recommended that proper mosquito-proofing of this dwelling should be carried out. The proofing should be done along the lines approved in Panama and other tropical countries, and not merely the fitting of so-called mosquito-proof doors and windows. Copies of the attached note on personal prophylaxis * should be given to all officials, etc., who intend going into the Gir Forest, so that they can use protective measures against this deadly infection. Copies should also be placed in the principal rooms of the rest-house. †

The cement tank in front of the rest-house should be oiled weekly.

(*b*) *The Village.*—The measures suggested for the river should have some effect on the incidence and severity of malaria, but will by no means abolish it. It is recommended that medical aid should be arranged for the villagers. If this is not possible, arrangements should be made through some responsible person in the village for the *free* distribution of quinine or cinchona febrifuge. If it were possible to get the villagers to take 10 grains of one of these drugs at least once weekly during

* Not reproduced here.

† Details of these measures are given by Covell (1930) in 'Anti-mosquito Measures, with Special Reference to India' (*vide* p. 361).

the healthier seasons of the year, and twice or even three times weekly during the more malarious periods, it should do much to diminish the sickness and mortality from malaria in the village.*

Part IV.

REPORT ON A MALARIA SURVEY AT BHAVNAGAR CITY.

Mosquitoes are reported to be very troublesome at some seasons of the year at Bhavnagar. A short survey was undertaken between 22nd and 24th April, 1929, to elucidate the cause of this prevalence, and to investigate the incidence of malaria in this area. Although the season was not that of the maximum mosquito prevalence, considerable light was thrown on the cause of this plague.

A. Topography, Etc.

The geographical position of Bhavnagar City is 21° 45′ N. and 72° 12′ E. It is situated about one mile from the south bank of the Bhavnagar Creek, and about 7 miles from the entrance of this arm of the sea into the Gulf of Cambay. The population of the City is about 64,000. The inhabitants live mainly in the City proper, in which there are few large open spaces. The City is surrounded by extensive residential suburbs, where are situated palaces, official residences, bungalows with large compounds and public gardens. The main portion of the City is built on an elevated site sloping towards the Creek. The northern portion has extended on to the flat land along the bank of this arm of the sea. †

There is a piped water-supply to the area, but wells are also in use. Those towards the lower parts of the City are brackish, and are used only for watering animals or for washing purposes.

The chief sources of water in the area may be classified as follows : -(1) The nullah below the Govrishankar Lake ; (2) Reservoirs and tanks ; (3) Wells ; (4) Water supply ; (5) Water-storage and ornamental tanks ; (6) Waste water ; (7) Irrigation ; (8) Rain water ; and (9) the Creek.

(1) *Nullah below the Govrishankar Lake.*

The Govrishankar Lake has been formed by the erection of a dam across a natural watercourse. This channel runs northward along the western side of the City, parallel with the area occupied by the palaces and official residences, and within a few hundred yards of them. The nullah has a wide bed from the Lake until it ends in the Moti Talao. There is a narrow stream wandering down this bed with grass-grown edges and a very winding course. Many pools are present in connection with this stream. These are overgrown with reeds in some cases, while in others

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* These are daily doses for adults, and proportionate doses should be given to children.

† Some meteorological data have been given in Appendix I.

they have grass-grown edges and much aquatic vegetation. The water in many places is comparatively clean but there are other pools used by washermen, in which the water is dirty and has little vegetation. In addition to pools connected with the stream, there are others due to the very numerous borrow-pits which have been dug in the nullah bed. This nullah was found to be breeding *A. culicifacies*, *A. stephensi*, *A. fuliginosus*, *A. subpictus*, *C. fatigans*, *C. vishnui* and *C. bitaeniorhynchus* in large numbers. After the monsoon this nullah must contain more water than in April. There must then be an enormous increase in the number of mosquitoes breeding in it, especially as many of the borrow-pits, now dry, must become filled with water.

(2) *Reservoirs and Tanks.*

No breeding was found to be taking place in the Govrishankar Lake, probably on account of its clean-cut edges and the numbers of fish present. There was a certain amount of floating débris against the corners of the dam, which might afford shelter for larvae at some seasons of the year.

The Moti Talao is a large elongated tank formed by damming the nullah mentioned above, at its lower end near the Creek. This tank has very reedy edges and much aquatic vegetation among these reeds. It lies within a few hundred yards of the lower portion of the City and was found to be breeding *A. culicifacies*, *A. hyrcanus*, *A. subpictus*, *C. fatigans*, *C. vishnui* and *C. bitaeniorhynchus*. The number of larvae found in any one spot were small, but on account of the large area of this tank, the total number of mosquitoes produced must be very considerable.

There is a large tank, the Gungajalia Talao, in the centre of the City. This was dry in April and I understand that it is not proposed to refill it with water in the future. After the rains, breeding pools may form in depressions on the bottom of this tank.

(3) *Wells.*

The wells in the upper portions of this area contain fresh water and are about 20 feet deep, while in the flat areas towards the Creek the level of the water is only a few feet from the surface, and it is brackish. The wells in the suburban portions of the area are mainly used for irrigation purposes, while those in the City, if fresh, are used for drinking water, and the brackish ones for washing, etc. Those wells which were in constant use contained few or no larvae, but larvae (? *A. stephensi*) were present in some of the disused wells, the surface of which was covered with floating débris. The shallow brackish wells in the lower portion of the City were in several instances breeding *A. subpictus* and Culicines.

(4) *Water Supply.*

The main reservoirs at the Pumping Station were not found to be breeding mosquitoes, but should be watched, as they may do so at other seasons of the year.

(5) *Water-storage and Ornamental Tanks.*

These tanks are numerous, more especially in compounds and gardens. As the water in them is clean, they afford very suitable places for mosquito-breeding, more especially those tanks in which there is any aquatic vegetation. Such tanks were found to harbour the larvae of *A. culicifacies* and probably breed other species, such as *A. stephensi, A. subpictus* and Culicines at other times of the year.

(6) *Waste Water.*

The arrangements for the disposal of waste water are very inadequate. Around wells, stand-pipes, watering troughs, etc., there are usually stagnant pools of water lying. Both Anophelines and Culicines were breeding in these. The larvae found were chiefly *A. subpictus* and *C. fatigans.* In various parts of the area, more especially in low-lying localities, the drains for waste water were blocked and formed large pools. Mosquito larvae, more especially those of Culicines, were found in these in very large numbers.

Some of the bungalows visited either had no proper facilities for the disposal of waste water from cook-houses or else this was collected in sumps. The water in these places was found to be a fruitful source of mosquitoes, and seemed in April to be responsible for much of the mosquito nuisance in bungalows.

(7) *Irrigation.*

The irrigation inside the area examined seemed to be entirely from wells and was mainly employed for gardening purposes. The water did not appear to be used in such excess as to form breeding-places. Wells in constant use did not seem to be a fruitful source of mosquitoes, but these insects were found breeding in disused wells.

(8) *Rain Water.*

The average rainfall is about 26 inches per annum. The short survey of the area would seem to indicate that during the dry season of the year the main cause of the mosquito nuisance is man-made, i.e., waste water, etc., but in the monsoon the number of breeding-places must increase very considerably. The large numbers of borrow-pits in some areas must become filled with water. The arrangements for the disposal of storm water from the area did not seem adequate. It is impossible, however, to give a definite opinion on this matter without having seen the wet weather conditions. The slope of the land in the residential area should permit of proper drainage, while towards the Creek the rise and fall of the tide would help these arrangements.

(9) *The Creek.*

This runs to the north of Bhavnagar and the tide has a rise and fall of 20 to 30 feet. At low tide the Creek lies between high clean-cut banks in this locality, but the banks stretch towards the town in a series of mud flats, which are liable to flooding at unusually high tides. There are a number of depressions on this land

and also salt-pans, but the water in these during April was so salty that no larvae were found. A number of small channels meander across these flats carrying seepage and waste water from the town. Many of these were found to contain both Anopheline and Culicine larvae in abundance. This was especially the case near the town, where the channels are continuous with the waste-water drains and contain stagnant pools.

B. THE MOSQUITOES OF BHAVNAGAR.

The mosquitoes of this locality must be considered from two points of view, namely, the carriage of disease and the nuisance produced by their bites. In Bhavnagar it was mainly in connection with the latter problem that advice was asked.

The following species of Anophelines were found :—*A. culicifacies*, *A. stephensi*, *A. fuliginosus*, *A. hyrcanus* and *A. subpictus*. The two species first mentioned are two of the most dangerous carriers of malaria in India. The next two, while reported to carry the disease, have not been found of much importance in this country. The Culicine mosquitoes found were *C. fatigans*, *C. vishnui* and *C. bitaeniorhynchus*. As the duration of my visit was brief, and made at a time when mosquitoes were much less common than in the rainy season, it is almost certain that other species are also present.

Other diseases which are known to be conveyed by mosquitoes in India are filariasis and dengue. Both these diseases are known to occur in the neighbourhood of the Gulf of Cambay. Dengue is conveyed by Culicines and it seems probable that many of the ailments recorded under the term ' fever ' in this area may be due to this disease. Several of the Anopheline and Culicine mosquitoes recorded from this locality are known to be carriers of filariasis. Apart from the annoyance caused by their bites, it seems probable that the mosquitoes of Bhavnagar may be responsible for the spread of other diseases besides malaria.

(1) *Breeding-places of Mosquitoes.*

A list of the chief breeding-places found in April and the species of mosquito identified are listed in Appendix VIII. It must not be thought that these are the only breeding-places in the Bhavnagar area, for it was impossible in the short visit to make an exhaustive survey. The records, however, indicate what may be expected in other parts of the area under the same conditions.

In describing the various sources of water in the area the different types of breeding-places have been described. From the data in Appendix VIII and the notes on the sources of water, it will be seen that the main breeding-places of the dangerous carriers of malaria were :—

(*a*) *The Nullah* which runs from the Govrishankar Lake into the Moti Talao. The chief breeding-places are in the upper part of the nullah, a few hundred yards from an important residential area where the palaces and official residences are situated. The lower portion is close to the City. The numbers of dangerous mosquitoes breeding in this nullah must be much increased after rain.

(*b*) *Water-storage tanks, fountains, etc.*—Larvae have been found in these. more especially in the presence of aquatic vegetation. The close proximity of these tanks to dwellings makes them an important factor in the spread of malaria.

(*c*) *Wells.*—These are a favourite breeding-place of *A. stephensi,* but in the cases where wells were in continuous use the conditions were such that few larvae were found. If, however, the wells are not used and contain aquatic vegetation or floating débris, they afford suitable breeding-places.

With regard to the mosquito nuisance, the breeding-places responsible for these were chiefly man-made :—

(*i*) The absence of proper means for the disposal of *waste water* is responsible for myriads of mosquitoes. In the residential area, these are breeding in waste water from cook-houses, bath-rooms, stand-pipes, etc. In the City proper these conditions are also present, but to a less degree. Here the main factor is that the drains are in many instances blocked, and form stagnant pools which contain innumerable larvae. In the lower part of the town towards the Creek, these drains have not sufficient gradient to allow the water to flow away and flush them properly. The result is that many stagnant pools are present. The ground around stand-pipes and watering troughs is usually a quagmire. No proper outlet has been arranged for some of the drains, with the result that they terminate in grass-grown swamps. These conditions of insufficient arrangements for the disposal of waste water, seem to be the main cause of the mosquito nuisance during April, and probably at most other times of the year.

(*ii*) During the rainy season and afterwards, breeding-places in the *hollows and depressions* in the large nullah, as well as in similar places in any part of the area which are not properly drained, must add considerably to the plague of mosquitoes.

(*iii*) *Wells, water-storage tanks,* etc., add their quota, but the numbers are probably small in comparison with those derived from the sources previously mentioned.

(*iv*) On account of the large breeding area formed by the *Moti Talao* it must produce a very considerable output of adult mosquitoes, although the numbers of larvae found in any one place were small.

(2) *Adult Mosquitoes.*

Very few adult Anopheline mosquitoes were seen, but this was probably because time did not permit of a prolonged search. Culicines were present in very considerable numbers in the Rest Camp, so that a mosquito net was essential to obtain a peaceful night. These seemed to be breeding in local collections of waste water.

(3) *Summary.*

The malaria-carrying mosquitoes seem to be breeding chiefly in the nullah and water-storage or ornamental tanks, while the mosquito nuisance in April seemed to be mainly due to the accumulations of waste water.

C. Incidence of Malaria in Bhavnagar.

Dr. Ferozeshah Motiwala, Chief Medical Officer, Bhavnagar State, very kindly had a splenic census taken of the children at Bhavnagar City before my arrival in April. The results of this census are given in Appendix IX.

In this census 10,804 children were examined and of these only 254, or 2·4 per cent, were found to have splenic enlargement. This is a very low splenic index, and would indicate that the average incidence of malaria in this area is extremely low. The highest rate, 8·6 per cent, was among children of a low social status living in the Upper Kot. Even this rate is not very high.

From the facts elicited by the mosquito survey, one would not expect a high average spleen rate in Bhavnagar during April. The rate will probably be greater after the rains, but the low rate in April indicates that severe malarial incidence is not a common feature of Bhavnagar at this time. It may possibly occur under exceptional conditions of rainfall, etc.

As has been found during my Kathiawar tour, malaria is not as a rule generally present, but localized areas occur in which the incidence of the disease is high. Such areas have been found to be in close relationship to permanent breeding-places of dangerous malaria-carrying Anopheline mosquitoes. So in Bhavnagar one would not expect a high incidence of this disease in the City proper, although the mosquito nuisance may be bad. One would, however, expect malaria to be common in habitations in the proximity of permanent breeding-places, such as the large nullah and the Moti Talao, as well as in houses in whose vicinity were water-storage tanks, disused wells and depressions containing water during the rains.

In Appendix X are given the figures for the number of patients treated for 'malaria' during the past 5 years. The number of patients recorded seems high. In considering these figures one must remember that many patients suffering from short pyrexias such as sandfly fever, dengue, paratyphoid fever, etc., are diagnosed as 'malaria,' when the facilities for routine examination of large numbers of blood smears are not available. It seems to me that these figures, in view of the low Anopheline prevalence and the low recorded splenic index, must contain a very considerable number of cases of other short fevers. These may so closely simulate malaria clinically in their febrile symptoms when seen as outdoor patients, that a proper differentiation could only be made by blood examination. The large numbers of Culicine mosquitoes found breeding would suggest that many of these fevers may belong to the dengue group of fevers.

D. Anti-mosquito Measures Suggested.

(1) *General Recommendations.*

As the plague of mosquitoes causes such a nuisance in Bhavnagar it seems to me that it would be advisable to appoint a whole-time officer to deal with the problem. This officer should be provided with the necessary staff of Sanitary Inspectors and coolies to carry out such works as minor drainage, filling borrow-pits, oiling, etc.

In the case of residential areas and gardens, it should be possible to enforce some regulation making the owner or occupier of any premises responsible that it is kept free from mosquito-breeding. The anti-mosquito officer could advise such persons as to the best manner to accomplish this. The breeding of mosquitoes should be considered a 'nuisance' under the Sanitary Acts. The discovery of larvae on any premises should be sufficient proof that such a 'nuisance' exists and the person responsible should be dealt with. Regulations of this kind have been enforced with great strictness for many years in the United States of America and in some other countries.

It must, however, be remembered that mosquitoes may fly for considerable distances. Even if the occupier of a compound keeps his own area free from mosquito larvae, his efforts may be nullified to a considerable extent by an invasion of mosquitoes bred in other neglected compounds and land in the vicinity. It is, therefore, necessary that the regulations should be enforced.

A publicity campaign would probably aid matters in directing and educating public opinion as to the dangers of malaria, the necessity and means of mosquito destruction and the need for co-operation by the people themselves in the abolition of the mosquito nuisance and of malaria. In many Bengal villages such co-operative movements have been started with a considerable degree of success.

(2) *Waste Water.*

This seems the main cause of the mosquito nuisance in Bhavnagar in April and probably at other times of the year. Blocked drains, stagnant pools in drains, swamps formed at the outfall of drains, waste-water sumps, pools around stand-pipes and watering troughs, etc., are forming breeding-places which produce innumerable mosquitoes. The oiling of such places once weekly would help to diminish the number of mosquitoes, but this is a large problem and can only be solved in a satisfactory manner by some proper system of disposal of waste water. Until such a system of drainage is arranged for, with proper channels, proper gradients and a proper outfall, there will probably always be a plague of these insects.

Covered pits for waste water from cook-houses and baths should diminish the breeding-places in the residential areas, especially if these are oiled weekly. In the City, however, some proper means of disposal of such water is urgently needed.

The present system of 'kutcha' drains with insufficient gradient over the flat land towards the Creek is responsible for much mosquito-breeding in the northern part of the City.

(3) *Wells.*

All unnecessary wells should be filled in, or else properly covered to prevent the access of mosquitoes to them. Wells not used for drinking purposes should have their surfaces kept free from floating débris and vegetation and be oiled once weekly, if they cannot be closed. If certain wells must be kept uncovered for drinking

purposes, they should be examined periodically for larvae, and if these are found they should be treated with petrol.

(4) *Water Storage, Ornamental Tanks and Fountains.*

The water-storage tanks in gardens, etc., should be oiled weekly. Ornamental ponds, fountains, etc., should be kept free of vegetation of all sorts and oiled once weekly. In some of these the introduction of small fish might be tried, as recommended at Rajkot. In this case the tanks should be kept free of floating vegetation. If the trial is found successful, the same measures might be used in other tanks and possibly in wells.

(5) *The Nullah.*

The close proximity of this breeding-place to the west side of the area and the fact that it is breeding dangerous carriers of malaria in considerable numbers, makes it a very important factor in relation to malaria in Bhavnagar.

The question of subsoil drainage might be considered in the upper part of its course. The fact that this is one of the main storm-water channels of the northern part of the area, makes it doubtful whether subsoil drainage would be capable of dealing with the nullah in the wetter season of the year. As a proper drainage system is recommended for Bhavnagar it seems to me that a proper open drain down this nullah could be made to collect the drainage from a large number of the storm-water drains of this locality and so avoid duplication of drainage works.

As a temporary measure it is recommended that a central drain be cut down the middle of this nullah. This would collect the water into one main channel, and prevent it from wandering vaguely along the bed as at present. This channel should be as straight as possible, should have clean-cut edges, and should be suitably graded to prevent the formation of swamps and stagnant pools. All swamps, depressions, pools, etc., in the nullah should be filled. The portions of the bed on each side of the central channel should be given a slope towards it, so that pools are not left after rain. This central drain and any collections of water in the nullah should be oiled weekly. The formation of borrow-pits in the nullah should be forbidden.

The above is only a temporary measure, and should be carried out before any permanent work is done, whether of subsoil or open drainage. When this drain has been made, it should then be possible to estimate the size and character of the permanent drains necessary to deal with the amount of water in the nullah at different seasons of the year. It will also be possible to decide how this channel can be fitted into the general scheme of drainage proposed. Such a drain should reduce the number of breeding-places to a considerable extent, so that the execution of anti-mosquito measures will be greatly facilitated.

It may be found from observations made in the monsoon that the amount of water in the nullah is too great to be dealt with effectively by subsoil drainage. It is suggested that under these circumstances, the temporary drain be converted into a 'pukka' channel of a size capable of dealing with the amount of flow observed in

the temporary drain. In my opinion this would probably best be done by converting the nullah into a channel with stone-pitched sides and a central brick or stone cunette of a size sufficient to deal with the perennial flow.

From the top of the stone-pitching the ground should be sloped upwards towards the banks of the nullah and planted with grass to prevent scouring during the rains. The nullah bed should be kept free of jungle.

The use of paris green in the nullah at present would probably reduce the incidence of malaria in the adjacent residential area, but would have little effect on the mosquito nuisance.

(6) *Water Supply.*

The storage reservoirs were not found breeding mosquitoes in April but should be examined periodically to determine whether this occurs at other seasons of the year. Mill ponds should also be kept under observation.

The manholes in the covering of the drinking-water storage reservoirs should be closed with a finer mesh of wire gauze.

(7) *Large Tanks.*

The Govrishankar Lake was not found breeding mosquitoes. The Moti Talao was producing mosquitoes in considerable numbers, and the treatment of this place affords considerable difficulty if the tank is to be preserved. The use of paris green would reduce the number of malaria-carrying mosquitoes here, but would have little effect on Culicines, the main cause of the mosquito nuisance. If the Culicine larvae are to be destroyed, it is recommended that the margins of the Talao be kept free from weeds and floating vegetation. This measure should reduce the breeding considerably, but it may be necessary to resort to oiling as a subsidiary measure.

If the Gungajhalia Tank is to be kept empty, a watch should be kept to see that pools do not form in its bed during the rains. If these do appear they should be drained, filled or oiled.

(8) *Irrigation.*

This does not seem to be responsible for much mosquito-breeding, apart from disused wells. Care should be taken, especially during the rains, that irrigation channels are kept in good repair and free from weeds. The formation of pools in their beds or along their sides from seepage or breaches should be prevented.

(9) *The Creek.*

No larvae were found in this. The pools along the mud flats between the Creek and the City seemed to be too salty for mosquito-breeding in any numbers. It is possible, however, that after rain depressions and borrow-pits in this area may become filled with fresh water and form breeding-places. All pools and depressions likely to hold water should be drained, filled or oiled when necessary.

The waste-water and other channels, which wander over these mud flats, should be given a straighter course and a steeper gradient to prevent the formation of pools and swamps.

(10) *Rain Water.*

The arrangements for the disposal of storm water in the area should be investigated and proper channels made to prevent stagnation in any part of the area. Proper arrangements should be made for the ultimate disposal of this water. As far as could be seen during the dry season, the outfalls of several of these drains looked as if they formed stagnant pools and swamps during the rains. They have not been carried to their natural outfalls, either the Creek or some deep channel discharging into it.

(11) *Jungle, Scrub, etc.*

Compounds, etc., should be kept free of jungle, as this harbours mosquitoes, prevents drying of the ground and hides breeding-places of mosquitoes.

(12) *Conclusions.*

The main anti-mosquito measures recommended for Bhavnagar are intimately bound up with the question of the disposal of waste and storm water. A proper system of drainage is necessary to abolish the mosquito nuisance.

Part V.

REPORT ON A SHORT MALARIA SURVEY AT WADHWAN CAMP.

A short investigation was made into the prevalence of malaria and of mosquitoes at Wadhwan Camp between 25th and 27th April, 1929. As this is the driest season of the year further information would probably be obtained if another survey were made at the end of the wet weather.

A. Topography, Etc.

The geographical position of Wadhwan Camp is 22° 42′ N. and 71° 44′ E. It lies on the northern bank of the Bhogavo River and has a population of about 12,000. The area on which the town is situated slopes evenly towards the river.

The chief sources of water are (1) the River; (2) the Water Supply; (3) Water Storage; (4) Large Tanks; (5) Waste Water; and (6) Rain Water.

(1) *The River.*

At the time of the visit the river bed was practically dry, but here and there stagnant pools were present. The pools in the vicinity of the bank, on which the

town stands, were full of small fish and no larvae were found. Towards the opposite bank and in the bed above the town, a number of shallow wells had been dug in which Anopheline larvae were found. These were also present in seepage pools along the edge of the bank.

It is probable that after the rains many pools suitable for breeding mosquitoes are present in the river bed.

(2) *Water Supply.*

There is a piped water-supply to the town, but in addition there are a number of wells scattered over the area. Some of these are used for drinking purposes, some for irrigation, but many seem to be disused. As will be seen from the list of breeding-places given in Appendix XI, such wells were a fruitful source of mosquitoes.

(3) *Water Storage.*

Many of the bungalows have small tanks in their gardens for the storage of water, usually for watering flowers or for the use of washermen. Larvae were found very commonly in these tanks.

The reservoirs for the storage of the piped water-supply have not been found breeding, but they should be carefully observed, as they may do so at other times of the year. The cooling tanks of an electric-light engine were found to contain larvae.

(4) *Large Tanks.*

In April the water in the large tank at the west end of the station was not found to be breeding mosquitoes. It does not seem likely to be a great source of these insects, as the edges are fairly clean-cut and it contains very little vegetation. It should, however, be examined periodically.

The millpond at the Cotton Mill was not found to contain any mosquito larvae, but a tank at the Ginning Factory showed these in large numbers.

(5) *Waste Water.*

The waste-water sumps from cook-houses and bath-rooms were found, in some instances, to be breeding Culicine mosquitoes in large numbers, as were also some soakage pits. Around the stand-pipes and watering troughs, as well as in some of the roadside drains, pools of stagnant water are formed which contained larvae.

(6) *Rain Water.*

The average rainfall of Wadhwan is about 18 inches per annum. As April is the dry season, it is difficult to give an opinion on the state of the area in the rains. The storm-water drains in many cases looked as if they would contain stagnant pools

during the monsoon, and in many places there were depressions which must become pools of water at that season, unless proper steps are taken to prevent it. The arrangements for the disposal of rain water from the area did not seem adequate.

B. The Mosquitoes of the Wadhwan Camp Area.

The following species of Anopheline mosquitoes were found in Wadhwan:— *A. stephensi*, *A. culicifacies*, *A. turkhudi*, *A. fuliginosus* and *A. subpictus*. Of these *A. stephensi* and *A. culicifacies* are two of the most dangerous carriers of malaria known in India. Other species are probably present at different seasons of the year. The common Culicine was *C. fatigans*.

(1) *Breeding-places of Mosquitoes.*

In Appendix XI is given a list of some of the breeding-places found in the area and of the different species of mosquito found there. These give a good indication of what may be expected under similar conditions in any other part of the area at this time of the year.

(*a*) *The River.*—Pools in the bed were found breeding *A. stephensi* and *A. subpictus* in small numbers. Many more larvae are probably present after the rains.

(*b*) *The Water Supply.*—The reservoirs on the course of the piped water-supply were not found breeding, but should be watched, because such places are very favourite places in which to find the larvae of *A. stephensi*. The wells. more especially disused and little used ones, were found to be breeding large numbers of *A. stephensi* and *A. subpictus* as well as *C. fatigans*. The Anophelines from these sources must be responsible for much of the malaria transmission.

(*c*) *Water Storage.*—The tanks used for water storage have been found in many instances to be breeding myriads of the dangerous Anopheline, *A. stephensi*, as well as *A. subpictus* and *C. fatigans*. The close proximity of these tanks to dwellings makes them a very important factor in the incidence of malaria in Wadhwan.

(*d*) *Large Tanks.*—None of these were found to contain larvae in April, but they must almost certainly do so at other seasons of the year.

(*e*) *Waste Water.*—Collections of waste water from the various sources described were found to be breeding numerous mosquitoes on several occasions. The species found were *A. stephensi*, *A. subpictus* and *C. fatigans*. These must account for much of the mosquito plague in the houses nearby.

(*f*) *Rain Water.*—The condition of the area suggests that many breeding-places may be formed during the rains, and that they may last for some time afterwards.

(2) *Adult Mosquitoes.*

Numbers of adult mosquitoes were collected in bungalows and in servants' houses. These were found to be *A. stephensi*, *A. subpictus*, *A. culicifacies*, *A. fuliginosus*, *A. turkhudi* and very numerous *C. fatigans*. As was to be expected from the larvae found, the first two Anophelines and *C. fatigans* were much the commonest

species caught, the others being rare. The rarer species were probably breeding in pools in the river bed, or in places outside the area examined. It seems likely that *A. culicifacies* will be more plentiful at other seasons of the year.

C. Incidence of Malaria in Wadhwan Camp.

Records of splenic indices, parasite rates, morbidity and death rates from 'fever' were used in estimating the relative prevalence of malaria in this area.

(1) *Splenic Index.*

Dr. C. P. Doctor, Medical Officer, Wadhwan Civil Station, very kindly made a spleen census before my arrival and the results of his work are shown in Appendix XII. From this it will be seen that of 542 children examined 193, or 26·2 per cent, had enlarged spleens. This figure is much higher than the average found in any of the other large centres visited during my tour in Kathiawar. Such a spleen rate found at the time when the malarial incidence is low as compared with the autumn, indicates that there is a state of high endemicity in the area.

During my visit I examined 27 children of the sweeper class living in the Bhangi Ward, and found that 11 of these had enlarged spleens, i.e., an index of 41 per cent. The results of this examination are shown in detail in Chart IV, from which it will be seen that the apex of the average enlarged spleen was 8·7 cm. from the midline and 11·4 cm. from the umbilicus. Although the number of children examined were few, the results suggest that fresh infections were being acquired at this time of the year.

(2) *Parasite Index.*

Seven out of the 27 children examined were found to have malarial parasites present in their peripheral blood, i.e., a parasite rate of 26 per cent. Of these, five were *P. falciparum*, one *P. vivax*, and one a mixed infection with both parasites. Four children who had not enlarged spleens had parasites in their peripheral blood.

There was, therefore, evidence of malaria in fifteen children making a total of 55·5 per cent of the children examined.

(3) *Malarial Statistics.*

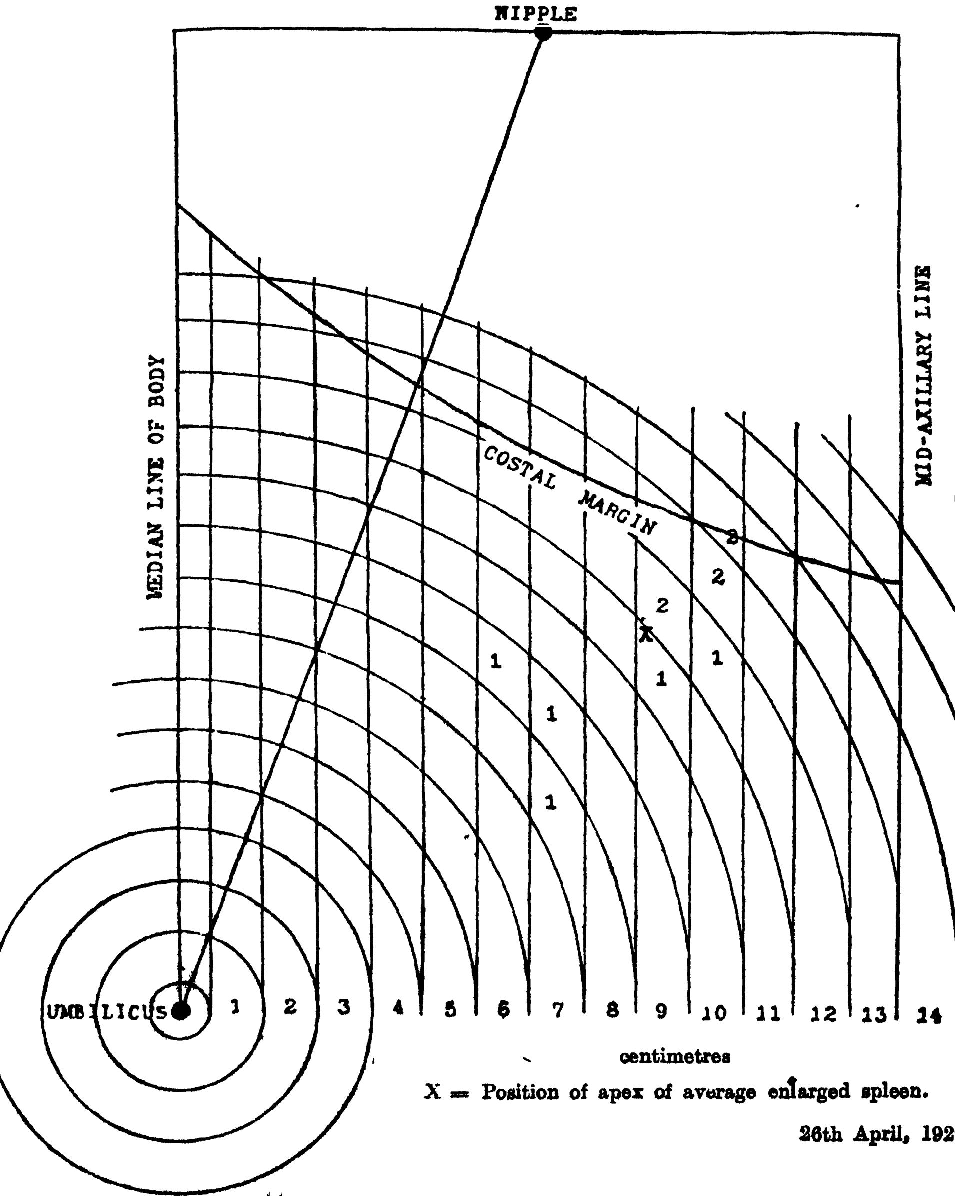
Figures of the attendances for 'fever' and the deaths recorded as due to this cause during the last three years have kindly been supplied by Dr. C. P. Doctor (Appendices XIII and XIV). From these it will be seen that the attendances at hospital for 'fever' rose markedly during the autumn months to reach a maximum in October and November. There was also a slight rise in March and April.

As the diagnosis 'fever' includes a number of diseases besides malaria, it must not be considered that all the cases recorded under this heading are of malarial origin. It has been found, however, in other parts of India that, in the absence of other epidemic diseases, these figures give a relative indication of the rise and fall of malarial incidence in a community. It would, therefore, seem probable that

Chart IV.

Results of Splenic and Blood Examinations at Wadhwan.

Blood examined	.. 27	Children examined ..	27
Positive findings :		Enlarged spleens ..	11
P. falciparum	5	Splenic index	41 per cent.
P. vivax	1	Measurements av. enl. spleen :	
Mixed	1	Apex-umbilicus ..	11·4 cm.
	—	Apex-midline	8·7 cm.
Total positive	7	Total number of children with evidence of malaria	15 or 55 per cent.
Parasite index	.. 26 per cent.	Number with gametocytes	2 or 7·4 per cent.



centimetres

X = Position of apex of average enlarged spleen.

26th April, 1929.

during the autumn months after the rains, malaria shows a marked increase in prevalence in Wadhwan, and possibly a slight rise in the spring months.

(4) *Summary.*

As might be expected from the large number of breeding-places of the dangerous malaria-carrier, *A. stephensi*, found in close proximity to dwellings all over the station, the splenic and parasite indices recorded are high. The high nature of these rates, especially at a period during which malaria is at a low ebb as judged by hospital statistics, indicates that this disease is very common in the area. It must account for a large amount of sickness and disability.

D. Discussion of the Results of the Survey.

The results of the survey may be divided into those connected (*a*) with the mosquito nuisance, and (*b*) with the incidence of malaria.

(*a*) *The Mosquito Nuisance.*

As can be seen from Appendix XI there are a very large number of breeding-places of mosquitoes scattered over the station, and the number of insects hatched from these must be great. The close proximity to dwellings of most of these breeding-places, more especially waste-water sumps, water-storage tanks, wells, etc., accounts for the numbers of mosquitoes in dwellings. It would seem that the main causes of the mosquito nuisance are man-made.

(*b*) *Malaria.*

The results of the investigations recorded above show that malaria is a prevalent disease in Wadhwan. The number of breeding-places of *A. stephensi* found in April would point to this insect as being a serious factor in the carriage of malaria in the spring, and probably at other times of the year. During and after the rains, accumulations of storm water in the area and in the river bed probably cause a great increase in the mosquito population. These are likely to include not only *A. stephensi*, but probably also that equally dangerous carrier of malaria, *A. culicifacies*.

The character of the breeding-places found seems to indicate that both the mosquito nuisance and the incidence of malaria in Wadhwan could be diminished considerably by comparatively simple anti-mosquito measures.

E. Remedial Measures Suggested.

(1) *The Wells.*

These are a fruitful source of mosquitoes all over the area. It is recommended that all disused wells should be filled in or properly covered, in such a manner that mosquitoes have no access to them. If wells must be kept for irrigation purposes. they should be oiled once weekly. If certain wells are needed for drinking water, it is recommended that these should be properly covered and pumps installed. If this is not feasible, they should be treated with petrol once weekly.

(2) *Water Storage.*

The water-storage tanks, ornamental ponds, etc., should be treated with oil or petrol weekly.

(3) *Large Tanks.*

These should be kept under observation as potential breeding-places, and should be oiled if larvae are found.

(4) *Waste Water.*

Waste-water sumps and soakage pits should be oiled weekly. Drainage should be provided to prevent the accumulation of waste water around stand-pipes, water-troughs, etc.

(5) *Water Supply.*

The large reservoirs for the storage of the piped water supply-should be carefully observed, and if larvae are found the tanks should be covered to prevent the access of mosquitoes. That breeding may take place in these reservoirs at some time of the year seems probable, and it is recommended that they be covered as has been done in Rajkot.

(6) *The River.*

The small pools found in the river bed should be oiled weekly. Larger pools should be kept free from vegetation and stocked with small fish.

(7) *Rain Water.*

Steps should be taken to establish a proper system for the disposal of storm water, so that stagnant pools are not formed after rain in any part of the area. Borrow-pits and similar depressions should be filled or drained, and the formation of such excavations forbidden in future. Large pits, which cannot be filled for financial reasons, should be kept free of aquatic vegetation and stocked with fish. If this is not feasible, they should be oiled weekly.

Several compounds were inspected in which there were marked depressions, which must fill with water after rain. Steps should be taken to fill or drain these. The drainage of storm water should not be difficult, as there is a good fall towards the river.

(8) *Miscellaneous.*

A Sanitary Inspector with a gang of coolies should be placed under the control of the Medical Officer, to carry out minor anti-malarial measures and report on the occurrence of mosquito-breeding in any part of the station.

As recommended in the previous reports on Kathiawar, the owners or occupiers of any premises should be made responsible for keeping them free from mosquito larvae. A publicity campaign would be useful to encourage this.

Appendix I.

Some Normal Meteorological Records in Kathiawar.

Rajkot.

Month and Year.	Temperature.		Relative humidity.	Rainfall.	
	Mean max.	Mean min.	Mean 8 A.M.	Average in inches.	Average number of rainy days.
January 1929 ..	83·6	51·1	52	0·04	0·2
February " ..	86·5	53·1	55	0·16	0·3
March " ..	94·9	61·9	61	0·07	0·1
April " ..	101·7	69·3	63	0·03	0·1
May " ..	105·1	75·1	67	0·43	0·6
June " ..	99·7	77·8	73	4·31	5·0
July " .	91·3	76·1	82	10·90	10·5
August " ..	88 8	74·5	83	5·71	7·8
September " ..	91·7	72·3	80	3·78	5·0
October " ..	95·6	68 3	65	0·65	1·2
November " .	90·9	60·0	49	0 23	0·3
December " ..	85·0	52·8	48	0·04	0 1

Bhavnagar.

Month and Year.	Mean max.	Mean min.	Mean 8 A.M.	Average in inches.	Average number of rainy days.
January 1929 .	84 1	54·8	54	0·13	0·1
February " ..	87·0	57·8	53	0·08	0·2
March " .	95·1	65 8	55	0·10	0·2
April " ..	101·7	73·9	56	0·10	0·2
May " .	105 0	78·2	64	0·44	0·9
June " ..	99·6	80·2	73	4·16	4·8
July " ..	93·3	78·6	79	6 72	8·8
August " ..	91·3	76·8	81	5·17	7·8
September " ..	93·0	75·1	79	3·33	5·6
October " .	96·2	70·4	62	0·75	0·8
November " ..	91·1	63·0	54	0·15	0·2
December " ..	85·3	55·9	54	0·07	0·1

Appendix II.

Breeding-places of mosquitoes at Rajkot.

	A. stephensi.	*A. culicifacies.*	*A. listonii.*	*A. subpictus.*	Culicines.
(A) *River Bed.*					
1. Rock pools below West Hospital ..	×	×	×	×	×
2. Foot-prints in sand below hospital ..	×	×	×	×	..
3. Stagnant pools below 'pukka' drain	×	..	..	×	..
4. Pools cut off from stream ..	×	..	..	..	×
5. Flowing pools at side main stream with vegetation.	..	×	..	..	×
6. Grassy pools connected with river ..	×	..	..	..	..
7. Seepage from nullah about 50 yards beyond end of 'pukka' drain.	×	..	..	×	×
8. Stagnant and running pools in river	×	..	×	..	×
13. Dirty pool near end of nullah ..	..	..	..	×	..
21. Numerous grassy pools and swamps near City wall.	×	..	..	×	×
22. ditto.	×	..	..	×	×
(B) *Nullahs.*					
(*i*) Nullah formed by junction of nullahs A and B.					
14. Pool near drain under bridge ..	×	..	.	×	×
15. Filthy pool under bridge ..	..	..	..	×	..
16. Pools in nullah under bridge ..	×	..	..	×	.
17. Grassy pools at sides stream in nullah	×	..	×	..	..
18. Buffalo wallow in nullah—many Anopheline larvae.	..	..	..	..	..
(*ii*) Nullah B.					
10. Pool in nullah near Jubilee House ..	×	..	..	..	..
11. Grassy edge of stream in nullah ..	..	..	×	×	×
12. Pools with vegetation	×	×	..	×	×

APPENDIX II—*concld.*

	A. stephensi.	*A. culicifacies.*	*A. listonii.*	*A. subpictus.*	Culicines.
(*iii*) Nullah A.					
19. Filthy pool in bed—Anophelines and Culicines.	..	..	..	×	×
20. Foot-prints in bed of nullah ..	..	..	..	×	×
(*iv*) Nullah C.					
9. Stagnant pools full of vegetation—many Anophelines and Culicines.	..	..	..	..	..
(C) *Miscellaneous.*					
28, 29. Disused wells	×	..	..	..	×
24, 27. Sump for water storage ..	×	..	..	×	×
30. Blocked drains	..	..	..	×	×
31, 32. Fountain basins	..	×	..	×	..
33. Blocked soakage pits, waste-water sumps, etc.	..	..	..	..	×

APPENDIX III.

*Statement showing number of attendance for 'fever' or 'malaria' month by month.**

West Hospital, Rajkot.

Month.	1926	1927	1928	Average.
January ..	280	153	161	198·0
February ..	163	154	184	167·0
March .	248	145	248	213·6
April ..	207	207	251	221·6
May ..	132	240	216	196·0
June ..	115	261	207	194·3
July ..	203	391	219	271·0
August ..	328	547	173	349·3
September ..	262	602	220	361·3
October ..	321	633	277	410·3
November ..	335	460	227	340·7
December .	174	260	127	187·0

* Figures kindly supplied by Major J. B. Hance, O.B.E., I.M.S.

APPENDIX III—*concld.*

*Monthly attendance for 'malaria' at Rajkot City Dispensary.**

Month.	1927	1928
January ..	364	322
February ..	364	295
March	364	328
April	376	421
May	376	419
June	376	419
July	461	417
August .. .	460	417
September .	460	417
October ..	360	464
November .	358	462
December ..	358	462
TOTAL .	4,677	4,843

Recorded 'fever' deaths for the quinquennium 1924—1928 were 2,864.

* Figures kindly supplied by Dr. N. K. Bam.

*Statement showing number of attendance for 'fever' or 'malaria' month by month.**

Colonel White Red Cross Dispensary, Rajkot Civil Station.

Month.	1926	1927	1928	Average
January .	80	26	70	58 6
February ..	50	49	38	45 6
March .	39	39	25	34·3
April ..	41	36	19	32·0
May ..	49	45	55	30 6
June ..	88	29	65	60 6
July ..	45	55	97	65 6
August .	72	91	81	81·3
September ..	58	257	118	144·3
October ..	111	269	112	164·0
November .	101	176	122	138 0
December ..	59	122	61	80·6

* Figures kindly supplied by Major J. B. Hance, O.B.E., I.M.S.

APPENDIX IV.

Some Mosquito-breeding places at Junagadh.

	A. stephensi.	*A. culicifacies.*	*A. subpictus.*	Culicines.
33. Stone trough near well in quarries behind Lancer Lines	×	×	..	..
34. Irrigation sumps beside Peri Talao	..	..	..	××
35. Irrigation drains at Peri Talao	..	..	..	××
36. Choked drain inside and outside Sardar Bagh ..	..	..	..	××
37. Tank around irrigation pipe, Sardar Bagh ..	..	..	×	×
38. Waste-water sump from kitchen, Sardar Bagh ..	..	..	×	××
39. Tanks for water storage near guard, Sardar Bagh .	..	..	×	××
40. Blocked drain at Hospital	..	..	?	××
41. Grassy pools in 'pukka' drain at Hospital ..	.	.	×	××
41*a*. Well in Hospital Compound	..	..	?	..
42. Disused well in City. (Much floating débris) ..	..	..	..	××
43. Pools beside watering trough outside gate towards Gondal.	..	..	××	..
44. Pools in Trivani Nullah	..	×	×	..
45. Other pools in Trivani Nullah	..	×	..	..
46. Dattar Tank	..	×	×	×
47. Pools in Damarkand Nullah	×	×	..	××
48. Kuwa	..	..	×	.
49. Cement water-storage tank in Mahabat Manzil ..	..	×	..	..
50. Blocked waste-water drain in City	..	..	××	..
57. Ornamental tank in Zoological Gardens	?	..	..	×
58. Tank with small crocodile in Zoological Gardens ..	..	..	..	××
59. Tank at Aman Mahal Palace	..	..	×	×
60. Khokharia Talao	..	..	×	..

APPENDIX V.

*Statement showing number of 'malaria' cases treated each month in Junagadh Civil Dispensary during the three years—1926, 1927 and 1928.**

Month.	1926		1927		1928	
	Total.	Average.	Total.	Average.	Total.	Average.
January	349	11·26	503	16·54	637	20·54
February	354	12·64	476	17·00	684	23·58
March	250	8·06	416	13·41	811	26·16
April	309	10·3	391	13·03	943	30·41
May	276	8·90	413	13·76	801	25·83
June	424	14·13	504	16·8	649	21·63
July	543	17·51	581	18·74	943	30·41
August	528	17·03	807	26·03	1,001	32·48
September ..	434	14·46	781	26·03	1,122	37·4
October	548	17·67	546	17·61	1,125	36·29
November ..	408	13·6	1,084	36·13	1,001	33·36
December ..	383	12·35	780	25·26	1,098	35·41

* Figures kindly supplied by Captain Mazumdar.

APPENDIX VI.

*Statement showing number of deaths recorded as due to 'ague' each year at Junagadh during the last 10 years.**

No.	Year.	Number of deaths.
1.	1919 to 1920, i.e., 1-4-19 to 31-3-20 ..	628
2.	1920 to 1921, i.e., 1-4-20 to 31-3-21 ..	434
3.	1921 to 1922, i.e., 1-4-21 to 31-3-22 ..	322
4.	1922 to 1923, i.e., 1-4-22 to 31-3-23 ..	226
5.	1923 to 1924, i.e., 1-4-23 to 31-3-24 ..	295
6.	1924 to 1925, i.e., 1-4-24 to 31-3-25 ..	364
7.	1925 to 1926, i.e., 1-4-25 to 31-3-26 ..	316
8.	1926 to 1927, i.e., 1-4-26 to 31-3-27 ..	428
9.	1927 to 1928, i.e., 1-4-27 to 31-3-28 ..	504
10.	1928 to 1929, i.e., 1-4-28 to 28-2-29 ..	376

* Figures kindly supplied by Captain Mazumdar.

APPENDIX VII.

*Statement showing percentage of school children of 10 years of age or younger with splenic enlargement during March 1929 at Junagadh.**

Name of schools.	Total number of school children.	Number of children with enlarged spleen.	Percentage of children with enlarged spleen.
Indian Girls' School ..	156	10	6·41
Laddi Bibi Girls' School ..	361	15	4·43
Lal Bakhte Girls' School ..	80	1	1·25
Aisa Bibi Girls' School ..	400	19	4·75
Taluka School	212	11	5·18
Balshala School	200	34	17·00
Danapith School	323	33	10·21
Jhalorapa School No. 3 ..	130	13	10·00
Mahalat—Madressa—Tul-Mulla	30	2	6·66
Mahalat Madressa	350	25	7·14
TOTAL ..	2,242	163	7·27

* Figures kindly supplied by Capt. Mazumdar.

APPENDIX VIII.

Some Mosquito-breeding places at Bhavnagar City.

	A. culicifacies.	*A. stephensi.*	*A. hyrcanus.*	*A. fuliginosus.*	*A. subpictus.*	Culicines.
60. Fountain basins in Palace grounds ..	×	..	..	..	..	..
61. Disused well in President's garden ..	×	..	..	..	..	×
62. Ornamental tanks in President's garden ..	×	.	..	..	..	..
63. Pools below embankment of Govrishankar Lake	..	..	..	?	..	×
64. Grassy pools in nullah below the Lake ..	..	..	.	×	..	×
65. Weedy tank in nullah below the Lake .	×	..	..	..	×	×
66. Stream in nullah from the Lake to first bridge..	×	×	..	×	×	×
67 and 69. ditto	×	..	..	×	×	×
68. Between first bridge and railway bridge in nullah.	×	..	..	..	×	××
70. From railway bridge to top Moti Talao ..	..	..	..	..	×	×
71. Moti Talao	×	.	×	×	..	×
72. Waste-water pool from bath house, Takhteshwara Plots.	..	.	..	.	×	×
73. Waste-water drain, Moti Bazaar	..	..	..	..	..	×××
74. Well, Raneswar Mandi Temple	..	..	..	..	×	..
75. Waste water in blocked roadside drain, Bander Road.	.	..	..	.	××	××
76. Shallow brackish well, Phanjewan Chakanda ..	..	..	..	..	×	××
77. Filthy blocked drain, Press Road	..	..	..	..	××	××
78. Well, Divampura Road (*Anopheles* sp.) ..	..	?	..	..	..	..
79. Brackish water in pools at end town drain, near Bandar.	..	..	..	..	××	..

APPENDIX VIII—*concld.*

		A. culicifacies.	*A. stephensi.*	*A. hyrcanus.*	*A. fuliginosus.*	*A. subpictus.*	Culicines.
80.	Waste water from watering trough, Bandar Road	..	..	..	..	××	..
81.	Pool from leaking stand-pipe	..	××	..	..	××	..
82.	Disused well in Peile Gardens (*Anopheles* sp.) ..	..	?	..	..	..	..
83.	Waste-water sump in Guest camp	..	..	..	..	..	××

APPENDIX IX.

Statement showing percentage of children with splenic enlargement at Bhavnagar City in April 1929.*

Nos.	Ward.	Children examined.	Cases of enlarged spleen.	Splenic index. Percentage.
I.	Nava Para	671	13	1·9
II.	Momnavad, Manekji's Wadi .. .	609	30	4·8
III.	Ranika	1,250	24	1·9
IV.	Koliwad, Karachalia Para	659	20	3·03
V.	Kanbiwad	1,019	29	2·7
VI.	Sutar Wad	150	8	5·3
VII.	Sakar Bazar Amipara	145	2	1·3
VIII.	Durbari Kothar	369	1	0·2
IX.	Vadva	1,707	29	1·1
X.	Panvadi Infantry Lines, Masania Chakala	453	20	4·4
XI.	Upper Kot†	151	13	8·6
XII.	Bhaga Talao	902	24	2·6
XIII.	Pirchhala, Bha's Street, and Mehta Street	1,310	16	1·2
XIV.	Gola Bazar Jamadar Street .. .	479	6	1·2
XV.	Mohta Falia, etc.	306	12	3·9
XVI.	Khoja Moholla, Savaigar Street, and Ambaji Mata's Wad	634	7	1·1
	TOTAL ..	10,804	254	2·4

* Records kindly supplied by Dr. Ferozeshah Motiwala.

† Mostly children of low social status.

Appendix X.

*Statement showing total numbers of patients treated annually for 'malaria' in Bhavnagar City.**

Year.	Patients treated.
1924	14,697
1925	15,761
1926	18,974
1927	18,968
1928	22,600
1929, January to March ..	4,993

Percentage of 'malaria' to all other diseases treated in Bhavnagar State annually.*

1924-25	16·2 p.c.
1925-26	16·1 p.c.
1926-27	17·9 p.c.
1927-28	19·9 p.c.

Malaria tops the list of all diseases treated.

* Figures kindly supplied by Dr. Ferozeshah Motiwala.

Appendix XI.

Some Mosquito-breeding places at Wadhwan Camp.

	A. stephensi.	*A. subpictus.*	Culicines.
84. Waste water around large well at western end of station ..	..	× ×	..
85. Square masonry water-storage tank in private bungalow .	× ×	..	..
86. ditto. Water surface covered with old leaves .. .	× ×	× ×	..
87. Waste-water sump from kitchen, private bungalow .. .	..	.	× ×
87*a*. Other water-storage tanks in garden, private bungalow	× ×	..	..
88. Cooling tanks for electric-light engine	× ×	..	..
89. Water-storage tanks in garden, T. G. School .. .	× ×	× ×	× ×
90. Water-storage tank in garden, Kaiser-i-Hind Gardens ..	× ×	..	..
91. Disused well in town	× ×	..	× ×
92. Soakage-pit for waste water	..	..	× ×
92*a*. Waste-water pit at Police Inspector's Quarters	..	..	× ×
93. Disused well in Deputy Political Agent's Bungalow ..	× ×	× ×	× ×
94. Disused well in T. G. School	×	..	..
95. Disused well near tank	× ×	..	× ×
96. Well, Mahant Building	×	..	..
97. Horse-trough and waste water, Cotton Market . .	× ×	× ×	..
98. Well in Cotton Market	× ×	× ×	..
98*a*. Well in Dharmsala (*Anopheles* sp.)	?	..	..
99. Tank in Ginning Factory	× ×	..	..
100. Well in Jail Garden	× ×	..	× ×
100*a*. Vithal Garh well	× ×	..	× ×
101. Small shallow wells in river bed	× ×	× ×	..
102. Overflow into river bed from well on south bank	× ×	× ×	..

Appendix XII.

Statement showing splenic index among school children at Wadhwan Camp (March 1929).*

Splenic Index.

	Normal.	Finger-breadths.†								Total.	Grand Total.
		1	2	3	4	5	6	7	8		
Boys ..	374	47	34	35	25	4	3	..	1	149	523
Girls ..	168	13	17	10	3	1	..	..	..	44	212
Total ..	542	60	51	45	28	5	3	..	1	193	735
Percentage	63·8	8 1	6 9	6·2	3·8	0 7	0 4	..	0 1	26·2	..

* Results kindly supplied by Dr. C. P. Doctor, Medical Officer, Wadhwan Camp.
† Measurements in finger-breadths of projection beyond the costal margin.

Appendix XIII.

*Monthly statement showing number of attendances for 'fever' or 'malaria' at Wadhwan Civil Station Dispensary.**

Month.	1926.	1927.	1928.	Average.
January ..	85	66	113	88 0
February ..	70	42	75	62 33
March	77	72	81	76·67
April	68	60	89	72 33
May	35	50	58	47·67
June	32	40	85	52·33
July	38	84	120	80·67
August	91	123	121	111·67
September ..	104	223	214	180·33
October ..	177	256	294	242·33
November ..	153	358	412	307·67
December ..	115	228	319	220·67

* Records kindly supplied by Dr. C. P. Doctor, Medical Officer, Wadhwan Camp.

Appendix XIV.

Statement of deaths recorded as due to 'fever' each month during the period 1919—1929 *at Wadhwan Camp.**

Month.	1919-1920.	1920-1921.	1921-1922.	1922-1923.	1923-1924.	1924-1925.	1925-1926.	1926-1927.	1927-1928.	1928-1929.
April	5	3	16	6	4	5	1	6	..	5
May	6	3	7	1	10	4	3	3	2	1
June	6	6	11	6	4	4	..	7	..	1
July	1	5	5	8	6	2	3	6	3	2
August	7	3	6	2	2	4	4	16	4	4
September ..	10	3	7	6	13	10	10	18	10	9
October ..	11	11	14	7	7	12	7	11	9	7
November ..	7	10	13	15	10	7	6	6	10	5
December ..	13	9	12	6	5	6	5	11	6	4
January ..	6	12	13	2	4	5	5	7	3	3
February ..	14	14	9	4	2	3	7	2	2	..
March	8	15	8	7	4	2	4	3	1	..
Total ..	94	94	121	70	71	64	55	95	50	41
Percentage ..	31·02	32·08	44·9	29·05	28·4	28·5	26·9	37·4	25·0	17·6
Total mortality from all causes.	303	293	269	241	250	224	205	254	201	232

* Records kindly supplied by Dr. C. P. Doctor, Medical Officer, Wadhwan Camp.

Records of the Malaria Survey of India, Vol. II, No. 3, September, 1931.

SOME OBSERVATIONS ON THE HIBERNATION AND 'WINTERING' OF ANOPHELINES IN THE PUNJAB.

BY

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Malaria Survey of India.

[April 18, 1931.]

CONTENTS.

Definitions.

A very useful account of work on hibernation has been written by Boyd (1930) whose definitions and descriptions are given below :—

Hibernation.—'Hibernation implies the carrying over of a species from one breeding season to another, by individuals, regardless of stage, who enter upon an inactive period during which their metabolic processes are temporarily retarded. It must be distinguished from retarded, though active, development during the winter season. If during the winter season, which marks the trough of the annual cycle, larvae of all stages are found in appropriate breeding-places, and if in convenient shelters blood-engorged females are found with ovaries containing developing ova, active development, not hibernation, is indicated. True hibernation of anopheline imagines does not seem to occur south of the 32nd parallel in the U.S.A.'

Signs of hibernation in the adults.—'True hibernation is accomplished only by the female imago, the males dying on the approach of winter. It would appear that females destined for hibernation are fertilized in the fall. Their fat bodies are large and give the abdomen a distended appearance. The ovaries are undeveloped. The hibernating females may be found resting on the inside of outbuildings, at times in large numbers. The mosquito draws in the last pair of legs, and assumes a position which brings the body close to the wall. The fat body is a many-lobed mass of tissue filling in spaces between the organs and the body-wall. It corresponds to the general segmentation, and is more or less symmetrically arranged. Masses occur on each side of the alimentary tract. Its cells are of considerable size. The cells contain numerous oil globules, granules and minute globules of a dark highly refractile substance, which are larger in old mosquitoes. The fat body probably furnishes a reserve supply of nourishment.'

'The imagines of some species do not hibernate, but die on the approach of winter. These species are carried over by hibernating larvae.'

'Reactivation of anophelines following hibernation is indicated, according to Swellengrebel, by the appearance of females carrying ripe ova, the appearance of larvae, and the reappearance of males (newly emerged).'

'Hibernation demonstrates that anopheline imagines can adapt themselves to extreme conditions of temperature and humidity within their habitat, yet, nevertheless, it would appear that many succumb to unfavourable conditions in these respects. High temperatures and low humidities appear disastrous to those kept in captivity, and exposure to the direct rays of the mid-day sun is likewise unfavourable. It would not appear that all females surviving at the approach of cool weather are able to enter upon hibernation, as a great diminution in their numbers is evident with the appearance of cool nights.'

Signs of hibernation in the larvae.—'The ova and larvae are well adapted to survive the rigors of winter in temperate and cold climates, and hibernation in either of these states appears the most important means of assuring the carrying over of a species into the following year in those regions where severe winters may be expected. In regions of severe climate, the survival of ova may be more common. Hibernating larvae abandon the water surface and seek refuge on the bottom, in which situation auxiliary means of respiration are doubtless called into play. Some observers think that hibernation is chiefly accomplished in the third and fourth instars.'

Wintering of anophelines.—'Anopheline mosquitoes are not uniformly abundant throughout the year even in the tropics, nor do all species attain their period of maximum abundance at the same season. The seasonal incidence of a species in more northerly latitudes will start from successfully hibernating larvae or imagines; in more southerly latitudes, with mild winters, active retarded development may continue throughout the winter. In latitudes with mild winters females may remain sluggishly active, and larvae of all stages may be found. In Europe stables are a favourite situation in which to pass the winter. Body radiation from the

live-stock mitigates the temperature, and the animals are occasionally utilized as food, as some blooded females testify. Some also over-winter in houses. Such females take advantage of warm winter days to venture abroad and deposit ova. At times large numbers of recently emerged anophelines may make a sudden appearance.'

'In such a winter period which is moderately severe, there is a progressive, though retarded, development of larvae in the warmer periods from the smaller to the larger stages. The wintering larvae survive best in those breeding-places, such as borrow-pits, which are not subjected to the scouring effect of rains.'

'Over-wintering accomplished, whether by hibernation or by retarded development, increasing solar radiation and precipitation set in train the forces that reduce the length of the generation span, and increase the breeding areas.'

'The phenomena of a seasonal maximum in the incidence of a given species appears dependent upon the temperature point at which larval development takes place with the greatest velocity. The shortening of the larval span at this temperature reduces the chances of mortality in the larval stage, and a larger proportion of adults emerge than is the case when the temperatures are less favourable. Furthermore, as long as this condition prevails. generations succeed each other with great rapidity, with progressively greater numbers of representatives. As the season advances, the temperature departs from this favourable point, the length of the larval span lengthens, larval mortality becomes greater, and the emergences become proportionately less. Replacement does not keep up with natural mortality, and the adult density declines.'

Thus, the species that have the temperature point of maximum velocity of larval development fixed at a higher level, may be called summer species, viz., *subpictus*. *vagus*, *stephensi*, etc.; and those having the point fixed at a lower level may be called winter species, viz., *fuliginosus*, *listoni*, *culicifacies*, etc.

'The duration of life in the imaginal stage differs in the sexes, while differences are noted also between the females of the summer generations and those emerging in the fall and destined for hibernation.'

Aestivation is a term that implies the ability of a species to resist the unfavourable periods of hot weather in the summer months or the dry season of the tropics.

Previous observations on Indian anophelines.

Christophers (1911), in his Memoir 'Malaria in the Punjab,' notes as follows (pp. 78–80):—

'During the cold weather when the night temperature may reach as low as 50°F., the larvae of anopheles are not found in open pools, but occur only in permanent waters containing much aquatic vegetation; even in this situation larvae are scanty during December and January.

'The first to note the species found under these circumstances and accurately to follow the course of events during the winter was James. He notes that the number of adult insects in the houses decreases during November and that the species *M. rossi* (*A. subpictus*) completely disappears, neither adults nor larvae being found after the end of November. In the case of *M. fuliginosus* and *C. pulcherrima*, on the contrary, adults were to be caught in reduced numbers in suitable places throughout the winter, and these species continue to lay their eggs and to go through their metamorphoses as usual. *M. culicifacies* was found to pass the winter in the larval stage, in which form it appeared to hibernate, the larvae being sluggish in their movements and growing very slowly, if at all.

'At Ferozepore, Adie notes that *N. fuliginosus* is found throughout the year and *M. culicifacies* very nearly so. *M. rossi* does not appear until July and disappears by December. *M. culicifacies* is common from about the first of May and disappears about the end of December. *N. stephensi* comes in about May and disappears about the middle of November. The common species as a whole are most numerous in September.'

The conclusions of Christophers (1911) may be summarized as follows :—

1. *A. fuliginosus.*—During the winter months *fuliginosus* was found breeding in large weedy tanks to the north of Amritsar city, and also in similar positions in the surrounding country. In March adults of *fuliginosus* were found at Amritsar quite commonly, and their larvae occurred in profusion in almost every suitable situation. But open pools free from weeds were still free from larvae.

2. *A. pulcherrimus.*—During the winter months at Amritsar, this species was found along with *fuliginosus*, but in much smaller number. By March these were found quite commonly.

3. *A. culicifacies.*—Larvae of *culicifacies* were first found at Amritsar in March, but the species was breeding in profusion in February at Atari, 15 miles away, where there were some very extensive and suitable breeding-places. This species was also found breeding at Beas and in the bed of the Ghagger at this time. By March this species was found quite commonly.

4. *A. stephensi.*—This species was first found in small numbers at Amritsar towards the end of February, but it was breeding in immense numbers in the wells and elsewhere at Delhi at this time, and was in fact the commonest species found there. *A. stephensi* was also found at this time (February) in considerable numbers at Beas. At Atari in February not a single specimen was found after much search. But this species was abundant in March both at Amritsar and at Atari.

5. *A. subpictus.*—During the spring of 1910 many thousands of larvae caught in different places in the Punjab were bred out, but though every other species was represented, no larvae of *rossi* were taken. In April many hundreds of adults were collected from the houses in all parts of Amritsar city, and specimens of all the plains species except *turkhudi* were found, but not a single specimen of *rossi* was among them. At Delhi in April though anopheles were not abundant, specimens of all other species mentioned were obtained, but there were no *rossi*. Such complete

disappearance of the commonest of all the species for so many months is very remarkable.

Hehir (1927) states that :—

'Some anopheles in India breed throughout the winter, especially in the southern coastal districts. Others, e.g., *A. culicifacies*, hibernate in the larval stage ; others, again, hibernate in the egg stage. The writer has often in India bred out anopheles from eggs contained in the surface mud of drying ponds and the lateral pools of streamlets that were drying up. In 1904, in Manipur, from local experience, he arrived at the conclusion that certain anophelines hibernated in the egg stage in moist earth. James and Liston consider that most Indian anopheles either manage to breed throughout the season or (e.g., *A. culicifacies*) hibernate as larvae.'

James (1920) says that :—

'Species which cannot exist in the adult form at certain seasons of the year pass through these seasons in the larval stage (e.g., *A. culicifacies*, *A. plumbeus*) or in the egg state.'

Utility of the research.

The mode of hibernation of the malaria-carrying anophelines is of great importance to malariologist, for with a knowledge of this he may be able to attack them at the time of their lowest density in their appropriate habitat, and consequently with the minimum expenditure on insecticides.

In rural areas in many parts of India, thatch-roofed houses have a sort of enclosure below the roofs, and the hibernating and wintering anophelines find their shelter in that enclosed space, where the temperature is much warmer than outside. They can also obtain any necessary food from the domestic cattle or the human beings occupying the rooms at night. Fumigation of these spaces in winter is likely to kill many of those anophelines which pass this season in the adult form, and would probably be an effective measure in reducing malaria in the locality if they include the chief malaria-carrying species.

To some of the large Indian industrial concerns, e.g., Tea and Jute firms, etc., which have to deal with large labour forces aggregated in barracks and lines in malarious places, this knowledge would also prove of great benefit. It would enable their Health Officers to reduce malaria by destroying the anophelines by fumigation, if the construction of the habitations could be so modified as to form such an enclosure below the roof where important anopheline species may be induced to collect for hibernation or wintering.

Likewise, those that are hibernating or wintering in the larval stage can be effectively reduced with less cost than would be possible in their breeding-season. If the chief malaria-carrying species of a locality are found to pass the winter as larvae, a thorough application of larvicides to their breeding-places towards the end of the cold months when their reactivation or rapid development is likely to occur, would greatly economize the problem of malaria control there.

Under similar circumstances, anopheline eggs may also be destroyed on the sides of drying-up ponds and ditches by saturating the mud with strong chemicals like crude petroleum, phenyle, etc.

Even in places where hibernation does not take place, all the species of anophelines are greatly reduced in number during the winter, mainly owing to a retarded development of their larvae. An accurate knowledge of the period of growth of each species in the cold months would enable the sanitarian to regulate the interval of application of chemical larvicides to effect the destruction of certain species which are concerned with the spread of malaria in those places. As chemical larvicides are expensive for wide application, this knowledge would lead to economy in their use.

LABORATORY EXPERIMENTS.*

(*a*) *Result of stocking the cave* † *with adult Anophelines.*—From the last week of October adult Anophelines were collected from the neighbouring villages and placed in the mosquito-rearing cave in suitable cages. These cages were made of cotton netting supported on six stout wire frames, each about one foot square. Each species was kept in a separate cage. Besides raisins and pieces of wet lint, a cone-shaped shelter (like an inverted funnel) made of several folds of an old dark blanket was introduced. This was placed vertically in a corner of each cage to afford a dark warm corner if the species preferred to hibernate inside this. The following table shows the number of adults that were introduced in the cages during November 1930 :—

A. subpictus	1,312
A. fuliginosus	932
A. culicifacies	253
A. maculipalpis	76
A. listonii	23
A. pallidus	22

On the approach of very cool nights in the first week of December, *subpictus* began to diminish rapidly in number, while the other species showed a fairly steady but less rapid diminution. About the middle of December, when the night temperature came down to about 50°F., all the *subpictus* died. The other species also died off gradually in the following order :—*culicifacies*, *maculipalpis*, *fuliginosus*, *pallidus*, *listonii*. A few *listonii* survived even up to the end of January. Although majority

* These experiments were carried out at the Ross Field Experimental Station for Malaria (Malaria Survey of India), Karnal, Punjab.

† This cave is a low brick-built house with a projecting screened portico, where some water reservoirs have been constructed in imitation of mosquito-breeding places. The purpose of the cave is to rear out a large number of anophelines so as to have a constant supply of them for experiments.

of the adults preferred to sit inside and upon the blanket-cones, none of the species showed any tendency to enter into hibernation inside these, with the result that at the end of February all the cages were void of living adults.

(*b*) *Result of stocking the cave with anopheline larvae.*—Nearly 6,000 larvae at different stages of development of the following species, *culicifacies*, *subpictus fuliginosus*, *pallidus*, *hyrcanus* var. *nigerrimus*, *barbirostris* and *stephensi*, were placed in four big enamel bowls with mud and grass in them and kept under observation inside rearing cages. Throughout November they were breeding out at a slow rate, but by the middle of December breeding practically stopped, and many dead pupae were seen on the mud every morning. Later, larvae of the second and third instars died very quickly, and only a few fourth-instar larvae were found to lie sluggish on the mud. When these were touched with a piece of stick, they seemed to be inactive at first, but later gave a sudden jerk and floated up. But none of these survived the whole period of winter, and at the end of February only a few hundred dead pupae were found in the bowls. Many of these pupae were malformed.

(*c*) *Result of stocking eggs in the cave.*—Eggs of each of the species, *subpictus*, *culicifacies*, *fuliginosus*, *maculipalpis*, *listonii*, and *pallidus*, were put in water in Petri dishes. The larvae emerged from these within 3 to 5 days even when the night temperature was as low as 50°F., but the young larvae coming out of the eggs could not survive the temperature successfully. The larvae of *subpictus* all died in the first stage, but the larvae of the other five species showed development up to the second stage and then died. This shows that under the conditions of temperature in the mosquito cave (*vide* Appendix), rearing out of adults from eggs is not possible in winter.

Some eggs (over 100) of each of the following species—*subpictus*, *fuliginosus*, *maculipalpis*, *listonii*, *culicifacies*—were kept on moist mud for long periods. The following technique was used:—some mud was kept in a porous earthenware cup which was placed on the top of an enamel cup full of water. The lower end of the earthenware cup was kept constantly in contact with the water, so that the mud remained moist all through, the level of the water being regulated from time to time. The eggs were kept in this condition till the end of February, and were then transferred to water in some Petri dishes, which were kept under suitable conditions for hatching. None of the eggs hatched, showing that it was not possible for them to survive the temperature of the cave in winter under the conditions of the experiment.

(*d*) *Difference in the period of retarded growth in larvae of the different species in winter.*—During the first week in December eggs were obtained from one female of each of the following species, *subpictus*, *fuliginosus*, *maculipalpis* var. *indiensis*, *culicifacies* and *listonii*, caught in nature. The eggs were kept on water in covered Petri dishes in the verandah, where they were not exposed to direct sunlight. The temperature and humidity are shown in the Appendix The period of development was found to differ in the various species of larvae, although they were kept under the same conditions of food-supply during the period. Table I shows the results. The experiment was started on 3rd December, 1930.

TABLE I.

Species of Anopheles.	Number of eggs laid by one female.	Eggs hatched after	Date when first pupa was seen.	Date when last pupa was seen.	Minimum period for growth.	Number of adults obtained.
subpictus ..	157	3 days	..	..	..	all larvae died in the 2nd or 3rd stage in 12 days.
fuliginosus ..	105	3 days	17th Jan.	12th Feb.	42 days.	12
maculipalpis var. *indiensis*.	81	4 days.	19th Jan.	10th Feb.	43 days.	8
culicifacies ..	140	3 days.	12th Jan.	1st Feb.	37 days.	18
listonii ..	73	5 days.	28th Jan.	13 full-grown larvae still remain in the 1st week of March.	51 days.	19

To study the development of the various stages of larvae, I kept the eggs laid by one female of each of the following two species, *subpictus* and *fuliginosus*, under identical conditions of food and temperature, and the result is shown in Table II. The experiment was started on 7th September, 1930.

TABLE II.

Species of Anopheles.	Number of eggs laid by one female.	DATES OF ATTAINING THE DIFFERENT STAGES BY THE MORE ADVANCED* LARVAE.				Minimum time taken for growth to pupa.	Number of adults obtained.
		I	II	III	IV		
subpictus ..	113	8th Sept.	11th Sept.	13th Sept.	15th Sept.	10 days.	48
fuliginosus ..	143	8th Sept.	11th Sept.	14th Sept.	19th Sept.	18 days.	35

*All the larvae from the same batch of eggs do not grow equally; the more advanced larvae are those showing the quickest growth.

Under the conditions of the two experiments it appears that—

(1) Under the most favourable conditions of temperature and moisture, as in the month of September, the different species show variations in the period taken

by the larvae to develop from the egg to the adult stage. Most of the eggs seem to hatch into larvae, but the mortality in the first stage seems to be very great. In the other three stages the mortality is less. Finally, only one-third or one-fourth of the number of eggs laid develop into adults. All larvae do not grow equally, the last two stages and in some cases the last three stages, can be seen simultaneously.

(2) Under the most adverse conditions of temperature in the winter months, the period of larval development is much prolonged and varies according to the different species.

(3). The larvae of *A. subpictus* develop very rapidly in the summer months, but they do not grow beyond the third stage in the early months of winter, and die either in the second or in the third stage when the temperature comes down below 50°F.

(4) Mortality in the larval stage of all the species experimented with is much greater in winter than in summer.

(5) The larval stage of *A. fuliginosus* is more than twice as long in winter as it is in summer.

(6) The larval stage of *A. listonii* is remarkably prolonged in winter.

(*e*) *Influence of the daily maximum and minimum temperatures on the growth of Anopheline larvae.*—From the above experiments in the mosquito-rearing cave and in an open verandah, it appears that the cave is not at all suitable for rearing out eggs of anophelines to the adult stage in winter, while an open place (the verandah of the laboratory) is quite suitable for rearing eggs to the adult stage, although at a slow rate. Now the question arises 'why is the cave unsuitable?' Does rearing depend on a daily low minimum or a daily high maximum temperature? If the daily temperatures of both the places (*vide* Appendix) are compared, it appears that in the cave the minimum did not come down as low as in the open, but the daily maximum was constantly much lower than the maximum in the garden. So it becomes obvious that if the breeding-places can get a fairly high daily maximum temperature (above 70°F.), the development of the larvae of most of the species, except *subpictus*, will proceed at a slow rate even if the minimum temperature goes down below 50°F. every night.

This fact explains why some of the ponds at Karnal, which would produce larvae in summer, remain sterile throughout the winter; their position probably prevents them from getting the full benefit of the higher solar radiation which the others, in which larvae are found, enjoy. This is the case, particularly in winter, when the margin of safety is so much reduced.

FIELD OBSERVATIONS.

(*a*) *The different seasons at Karnal.*—From the climatic point of view the year at Karnal can be roughly divided into periods of four dry, four wet and four cold months, as in Table III.

TABLE III.

Months.	Seasons.	Usual range of temperature.	
		Min.	Max.
March, April, May, June	Dry	60°F.	115°F.
July, August, September, October	Wet	65°F.	100°F.
November, December, January, February ..	Cold	32°F.	80°F.

The conditions of temperature in the first or last month of each season naturally tend to approach the conditions preceding or succeeding it.

(*b*) *Search for adult anophelines.*—

1. *At Karnal.*—In one of the barracks at the Imperial Cattle-Breeding Farm at Karnal, a regular search is made for adult anophelines on every Monday for two hours in the morning by the same collector to observe the seasonal prevalence of the different species of the locality. As the weekly catch of the adult anophelines is done with regularity of time and labour, the numerical prevalence of the different species in various seasons can be judged fairly accurately (ignoring the question of zoophilism) from Table IV, which shows the results from April 1930 to February 1931 :—

TABLE IV.

Species of Anopheles.	Dry months.		Wet months.		Cold months.	
	Early (Mar.*-Apr.)	Late (May-June)	Early (July-Aug.)	Late (Sept.-Oct.)	Early (Nov.-Dec.)	Late (Jan.-Feb.)
fuliginosus ..	398	232	391	602	613	89
culicifacies ..	56	275	309	304	225	15
subpictus ..	0	44	468	262	143	1
stephensi ..	5	19	17	12	3	1
listonii ..	7	10	1	9	77	6
pallidus ..	0	0	6	29	21	0
pulcherrimus ..	1	3	27	23	3	0
maculipalpis var. *indiensis*.	0	0	1	4	0	0
hyrcanus var. *nigerrimus*.	0	0	1	19	3	0
barbirostris ..	0	0	1	10	4	0
maculatus ..	0	1	0	0	0	0

* Shows catch of April only.

Search for adults in Karnal city was hopeless, as the people could not be persuaded to allow us to enter their houses in the morning hours.

2. *In villages in the neighbourhood of Karnal.*—Table V shows the species of Anophelines that were found in four of the neighbouring villages during the three chief seasons. This illustrates the fact that most of the species which are found in the warmer months, are not encountered at all as adults in the houses during the late winter. This fact is consistent with the results of the laboratory experiments, viz., that one generation span (ovum to ovum) of these species (except *subpictus*) is so prolonged owing to low temperature as to cover the whole winter period (*vide* Conclusion).

TABLE V.

Villages.	Dry months.	Wet months.	Cold months.	
			Early (Nov.-Dec.)	Late (Jan.-Feb.)
Barauta	*fuliginosus* *culicifacies* *stephensi* *maculipalpis* *listonii*	*fuliginosus* *culicifacies* *subpictus* *maculipalpis* *hyrcanus* *pallidus* *listonii*	*fuliginosus* *culicifacies* *subpictus* *maculipalpis* *pallidus* *listonii*	*fuliginosus* *maculipalpis* *listonii*
Sahpur	*maculatus*	*fuliginosus* *culicifacies* *subpictus* *pallidus* *pulcherrimus*	*fuliginosus* *culicifacies* *subpictus* *pallidus*	*fuliginosus*
Saidpura	*fuliginosus* *culicifacies* *stephensi* *listonii*	*fuliginosus* *culicifacies* *subpictus* *stephensi* *pallidus* *hyrcanus* *listonii*	*fuliginosus* *culicifacies* *subpictus* *listonii*	*fuliginosus*
Kambopura	*fuliginosus* *stephensi*	*fuliginosus* *culicifacies* *subpictus* *stephensi* *pallidus* *pulcherrimus*	*fuliginosus* *culicifacies* *subpictus* *listonii*	*fuliginosus*

In late winter, *A. subpictus* was probably hibernating in some inaccessible places in the houses in the villages. The construction of the houses provides very suitable sheltering places for mosquitoes. I have noticed in most houses a kind of enclosed ceiling where cattle fodder, old linen, cow-dung cakes, etc., are stored undisturbed for many months. This place was very suitable for hibernating mosquitoes, but quite inaccessible to anyone wishing to collect them. Consequently, only the 'wintering' specimens sitting on the walls were captured.

(*c*) *Search for Anopheline larvae in the breeding-places at Karnal* :—Table VI shows the prevalence of the different species of larvae in winter in their breeding-places at Karnal, as compared with the species prevalent in the dry and the wet months. There are about 50 different breeding-places at Karnal, which have been grouped into five types, of which the first three are permanent breeding-places. This table shows that even in late winter this year the larvae of *fuliginosus*, *culicifacies*, *listonii*, *hyrcanus*, *barbirostris*, *stephensi*, have been found in those places. Moreover, a few larvae of *A. gigas* were found for the first time at Karnal n February 1931.

TABLE VI.

Types of breeding-places.	Dry months.	Wet months.	Cold months. Early (Nov.-Dec.)	Cold months. Late (Jan.-Feb.)
Ponds and tanks ..	*fuliginosus* *culicifacies* *subpictus* *stephensi*	*fuliginosus* *culicifacies* *subpictus* *hyrcanus* *barbirostris* *pallidus*	*fuliginosus* *culicifacies* *subpictus* *hyrcanus* *barbirostris*	*fuliginosus* *culicifacies* *hyrcanus* *barbirostris*
Drains	*fuliginosus* *culicifacies* *subpictus* *stephensi*	*culicifacies* *subpictus* *hyrcanus* *barbirostris*	*fuliginosus* *culicifacies* *subpictus* *barbirostris*	*fuliginosus* *culicifacies* *stephensi* *listonii*
Wells	*culicifacies* *stephensi* *listonii*	*fuliginosus* *culicifacies* *stephensi* *hyrcanus* *listonii*	*fuliginosus* *culicifacies* *barbirostris* *listonii*	*fuliginosus* *culicifacies* *hyrcanus* *listonii* *gigas*
Pools of water. ..	*fuliginosus* *subpictus* *stephensi*	*subpictus* *barbirostris*	*subpictus*	..
Rice-fields	..	*pulcherrimus* *hyrcanus*	..	..

(*d*) *Search for eggs on the drying-up mud in the breeding-places.*—This was done, but with negative results.

(*e*) *Comparison of this winter with the previous one.*—I have been told that the preceding winter (1929–30) was very severe, and no larvae of Anophelines could be found anywhere about Karnal. I have recorded in the Appendix the maximum and the minimum temperatures of last year (1929–30) observed in a Stevenson's screen in the garden, for comparison with those of the present year (1930–31). From the middle of December 1929 and throughout January 1930, the maximum in the shade was almost constantly lower than 70°F., while in this season it was above 70°F. always, except for a few days in late December and in early February. This also confirms the fact elicited from the laboratory experiments

that larval growth of most of the Karnal species (except *subpictus*) can take place at a slow rate if the daily maximum rises above 70°F.

CONCLUSIONS.

1. Of the twelve species of Anopheles that have been found at Karnal, viz., *fuliginosus*, *culicifacies*, *subpictus*, *stephensi*, *listonii*, *hyrcanus* var. *nigerrimus*, *barbirostris*, *pallidus*, *pulcherrimus*, *maculipalpis* var. *indiensis*, *maculatus* and *gigas*, the first seven are reckoned as common species which occur in large numbers in the most favourable season of the year; the next three occur in fair numbers; but the last two are rare species for Karnal.

2. Of the first seven species mentioned above, *subpictus* alone would appear to be a true hibernating species, probably in the adult stage. This conclusion is supported by the fact that its larvae cannot be found in the winter, and its prospects of survival in the egg stage are small. The laboratory experiments have shown that (*a*) its death as an adult is very rapid on the approach of the cool nights, and (*b*) its eggs if deposited on water hatch into larvae even when the temperature was below 50°F., and that these die at an early stage, and (*c*) its eggs kept on moist earth for testing their viability at the end of winter have given negative results. I could not find out the places of their hibernation, owing to their inaccessibility under the conditions obtaining in Karnal town and in the neighbouring villages. Further, I could not find its eggs in nature in the most likely places.

3. The species *fuliginosus*, *culicifacies*, *stephensi*, *listonii*, *hyrcanus* and *barbirostris* have been found both as larvae and as adults throughout the winter. The adults were captured with fresh blood in their stomachs, showing that they were not in a state of true hibernation in winter. Their number is however greatly reduced in winter owing to—

(*a*) Rapid death of the majority of the pre-winter brood on the approach of cool nights;

(*b*) Retarded growth of their larvae at low temperatures; growth of the larvae takes place in winter if the daily maximum temperature of the atmosphere rises above 70°F.;

(*c*) Greater mortality of the larvae at different stages at low temperatures.

Calculating from the length of their larval, pupal and adult stages in winter, it would appear that only one single generation span (ovum to ovum) can cover the whole winter period in the case of the above species.

If the case of *fuliginosus* is taken as an example, its life in winter would be—

Stages.	*Maximum period*, as observed in winter.
Ovum in water ..	3 days.
Larva	68 days.
Pupa	7 days.
Imago	21 days (estimated; not observed).
	Total 99 days, i.e., more than three months.

Thus, if one female deposits her eggs in the last week of November, her offspring would do so in the first week of the following March.

4. Regarding *pallidus*, *pulcherrimus*, and *maculipalpis* var. *indiensis*, I obtained the adults of only the last in an active condition, but no larvae in the breeding-places. My search for their larvae and adults was not sufficiently thorough to warrant any opinion about these, but I believe they behave like *fuliginosus* in winter.

5. *Maculatus* and *gigas* are two very rare species for this locality, only one *maculatus* adult being caught in May 1930, whilst 6 *gigas* larvae were obtained in a well at Karnal for the first time in February 1931.

Acknowledgments.

I wish to thank Dr. Macdonald, Officer-in-charge of the Ross Field Experimental Station for Malaria, for permission to use the data of the routine larval and adult collections made at Karnal. My thanks are also due to Jemadar Abdul Majid, I.M.D., and the staff of the Ross Field Experimental Station at Karnal, for their co-operation and help in these observations.

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APPENDIX.

Record of average weekly temperature and humidity observed at Karnal (Punjab).

November 1930—*February* 1931.

Months.	Weeks.	In a Stevenson's screen in the garden. Temp. Fahrenheit. Max.	Temp. Fahrenheit. Min.	Relative humidity.* 9 A.M.	Relative humidity.* 4 P.M.	Last year's temperature in the garden. Max.	Min.	In the mosquito-rearing cave. Temp. Fahrenheit. Max.	Temp. Fahrenheit. Min.	Relative humidity.* 9 A.M.	Relative humidity.* 4 P.M.
November	1st	83·3	50·7	46·1	29·2	87·5	52·7	70·4	65·7	58·1	40·4
	2nd	84·1	49·2	45·8	27·8	84·2	53·8	70·1	62·2	58·5	43·8
	3rd	83·0	52·0	61·4	37·1	83·4	48·0	71·8	59·4	71·5	57·8
	4th	80·8	52·2	56·1	36·7	78·1	43·8	70·8	50·0	70·7	53·7

* From January 1931, humidity was observed at 8 A.M. and 4 P.M.

APPENDIX—*concld.*

Months.	Weeks.	In a Stevenson's screen in the garden.				Last year's temperature in the garden.		In the mosquito-rearing cave.			
		Temp. Fahrenheit.		Relative humidity.*				Temp. Fahrenheit.		Relative humidity.*	
		Max.	Min.	9 A.M.	4 P.M.	Max.	Min.	Max.	Min.	9 A.M.	4 P.M.
December	5th	79·8	51·4	58·2	42·7	75·5	46·1	69·0	58·2	62·0	54·2
	6th	76·1	41·7	47·7	28·5	73 2	50·8	64·4	52·5	55·1	46·0
	7th	75·2	43·4	65·2	40·8	65·0	45·5	63·7	51·5	70·2	54·0
	8th	74·0	39·0	60·5	34·4	56·8	41·2	61·8	48·8	62·7	52·4
	9th	67·6	44·1	65·1	51·1	62·4	41·4	59·5	48·4	77·4	65·8
January	10th	75·2	43·8	87·5	39·4	65·5	39·5	65·0	51 4	81·1	46·5
	11th	75·2	43·5	88·0	38·8	67 4	45 1	64·7	52 2	78·0	49·1
	12th	75·8	46·7	80 1	36·8	61·4	38 8	66·0	54·0	72·2	42·0
	13th	72·8	43·5	80·7	37·4	68·4	51·5	64·4	53·5	72·2	42·7
February	14th	70·8	42·4	78 8	46 4	65·1	43·4	62·5	50·4	69·2	48·8
	15th	64·2	46·7	85·4	58·5	65·8	43 4	57·2	52·6	80·2	66·7
	16th	70·8	45·8	85·2	46·1	77·1	51·2	..	..	77 0	52·0
	17th	73·4	48·5	85·8	45·5	82·1	55 7	..	..	76·8	54·7

* From January 1931, humidity was observed at 8 A.M. and 4 P.M.

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REPORT ON AN INTENSIVE MALARIA SURVEY IN THE KARNAL DISTRICT, PUNJAB.

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[May 18, 1931.]

CONTENTS.

INTRODUCTION.

THE work here described was undertaken with the idea of obtaining, as far as possible, a consecutive history of the autumnal epidemic of malaria in the Punjab, of correlating the severity of this epidemic with the meteorological and other factors

concerned, and of studying the habits of the species of anophelines responsible for carrying the malaria. The general outline of the work undertaken followed the lines recommended by the League of Nations Malaria Commission (1927), with the necessary modifications for the difference of conditions in India from those in Europe. The recommendation of the Malaria Commission was 'We think that in every European country at least one area should be selected in which detailed observations in malaria should be made at regular short intervals (say monthly) for several years. The observations should be on all matters with which a complete " malaria survey " is concerned, but in particular they should include an endeavour to record accurately the amount and character of the disease month by month and year by year, and the numerical prevalence and infection rate of anopheles in the houses at the same intervals. Observations should be made as to the abundance of anopheles larvae in breeding-places in the neighbourhood of the houses at different seasons of the year. The work should include a systematic house to house search for cases, for taking blood films and for collecting anopheles. It is essential that the Laboratory Staff should have no difficulty in entering and examining the interior of any house, stable or other building. We are convinced that, of all records relating to malaria, the full and definite story of its course and progress from month to month and year to year in selected localities, accompanied by similar information relating to adult anopheles in the houses and other buildings, is the work that is most urgently needed at present from the point of view of prevention.'

The scheme adopted to obtain this consecutive picture was to make a preliminary survey of a number of villages within easy access of headquarters during the malaria season, when the majority of roads are impassable, and then to carry out periodical surveys in three sets of villages selected as follows :—

(1) A village which seemed, from what is known of the epidemiology of malaria in the Punjab, to be more likely than any other to have a serious epidemic if epidemic conditions prevailed, was chosen and examined carefully once a week throughout the malaria season, (2) three villages were chosen which appeared in the preliminary survey to be respectively the most malarious, the least malarious, and normal for the district ; these were examined as far as possible once a month, and (3) as many villages as possible were to be examined and re-examined at intervals throughout the malaria season. At the same time continuous collections of anophelines, both adults and larvae, were to be made around Karnal town to amplify and verify information obtained in the villages as to the seasonal occurrence of these insects, and their preference for different types of breeding-places.

The procedure on going to a village, whether on the first or any other subsequent occasion, was to collect as many children as possible, including school children and others, to take thick blood films from them by the method of Sinton (1924) so that if parasites were found they could be counted, and to palpate their spleens. This was done with the child in the standing position, and when the spleen was palpable it was measured by the method of Christophers (1924). While this examination was in progress one trained collector searched in the village for adult anophelines,

while another was at work examining all collections of water for anopheline larvae. When the examination of the children was finished, a survey of the village was made and findings of the collectors verified. House to house search for cases is not a practical proposition in a Punjab village; and it is usually impossible to examine the sleeping rooms of a house for adult mosquitoes, with the result that most of the collections of anophelines were made from the outside room of the house, in which men and cattle often live together.

The programme outlined above was carried out in full in 1929, but in 1930 the first part of the programme, the weekly examination of one village, was abandoned; partly because the weekly examination of the children produced a considerable amount of obstruction from their parents, who objected to it, and partly because it was found, when we visited the village in 1930, that the interest thus evinced in malaria had stimulated the school master to give prophylactic quinine to the children under his care, thus destroying the value of our observations.

At the commencement of the work it was intended to dissect all adult anophelines found in the village, but it was soon found that this was impossible if the remainder of the work was to be carried out, and it was therefore abandoned.

In order to secure accurate climatic information, a meteorological station has been maintained at headquarters, regular readings of the dry and wet bulbs, which are housed in a Stevenson's Screen, and a five inch rain-gauge being maintained.

DESCRIPTION AND CLIMATE OF THE DISTRICT.

The observations were made on villages within twenty miles of Karnal City, in the Karnal District, in the South-East of the Punjab. The district forms part of the vast alluvial plain below the Himalayas, which are about sixty miles away. The land appears to be absolutely flat and level, the highest mounds ever visible being those formed by the ruins of old villages on top of which the modern villages are usually built. In reality the land has a slope varying from one foot to one foot six inches in the mile to the South and East. There are no permanent streams or rivulets in the whole district, the rain falling in the monsoon normally sinking into the ground, or collecting and forming shallow swamps, many of which are now drained by tortuous channels joining the Jumna River. This runs about eight miles to the East of Karnal, and is the only permanent river in the district; there are in addition a number of watercourses in the North of the district which, dry for nine months of the year, are flooded by torrents from the hills during the monsoon.

Throughout the greater part of the district, and the whole of that part in which this work was done, the subsoil water is within fifteen to twenty-five feet of the surface, and is tapped by numberless wells from which the water is drawn for the irrigation of the land. Irrigation of almost all crops is necessary in this land of extreme heat and uncertain rainfall, and wells were the only source of water until the construction of the Old Western Jumna Canal by the Moghul Emperors. This canal pursued a tortuous course through the Karnal District, and was a great advantage in that it provided the agriculturist with water for his fields. It was an

almost equal disadvantage, however, in that it made the country through which it ran extremely unhealthy, a matter which became of grave concern on the establishment of a British cantonment in Karnal in 1806. The cantonment was abandoned in 1843, and two years later a commission was deputed by the Lieutenant-Governor of the North-Western Provinces to 'report on the causes of the unhealthiness which has existed at Kurnaul, and other portions of the country along the Delhie Canal, and also whether any injurious effects on the health of the people of the Dooab is, or is not, likely to be produced by the contemplated Ganges Canal.' This was the famous Baker and Dempster Commission (1847), which first made use of the spleen rate, devised by Dempster, as an index of malarial endemicity. The Commissioners made an intensive survey of the district, and reported that the prevailing unhealthiness was due to malaria, which sometimes assumed epidemic proportions, and that the malaria was partly attributable to canal irrigation. They did not, however, regard malaria as the inevitable result of canal irrigation, but as due to faulty alignment of the canal, which interfered with the natural drainage, with consequent formation of swamps and saturation of the naturally stiff soil with moisture. The knowledge thus gained was used in the construction of other canals, but it was not until some forty years later that any improvement was made in the alignment of this one. Ibbetson (1883), in his settlement report, noted that some 8 per cent of the canal tract was permanently under water, and the remainder saturated with water, with the result that heavy rain did not sink into it but ran into shallow drainage channels with an almost imperceptible slope, which overflowed and covered the country with water for miles.

This was the condition when, in 1885, the canal was re-aligned on the accepted principles that it should run along the top of the contours rather than along the hollows, that all natural drainage lines should be carefully preserved, and that soil already saturated should not be irrigated with canal water. As a result the canal now runs through dry country, with only occasional stretches of waterlogged land at its sides. The subsoil water level, except at the extreme bank of the canal, is rarely less than fifteen feet from the surface, rain rapidly sinks into the soil, and consequently the tendency to the formation of swamps has greatly lessened, while those that do tend to form have mostly been drained. The district has ceased to be the plague spot of the Punjab and is now relatively healthy.

The malaria history subsequent to this re-alignment of the canal has been quiet. Christophers (1911) described two great epidemic areas of the Punjab, one in the North and one in the South-East, Karnal District lying between the two and not being especially liable to great epidemics, though he notes that in 1900 a large epidemic included Karnal in its area of spread.

The monthly deaths for each Rural Circle in the district are preserved as far back as 1916, and an estimation of the epidemic figure for each year for each of the Rural Circles, the full details of which are given in Table A in the Appendix, shows that there have been three years of slight epidemic prevalence since that date, but no year of exceptionally heavy mortality. In 1921 there was a very small focus

of epidemic malaria in the region of Shahabad, in the North. In 1923 there was a generalized increase in the severity of the malaria over almost the whole of the district, except for some of the river-side tracts, while in 1925 the South-Eastern end of the district experienced a localized outbreak. It is worthy of note that in September 1924 the river Jumna overflowed its banks to an unusual extent, and flooded the land for several miles on either side, but that there was no increased prevalence of malaria in any registration circle in that year.

Table I, showing the relation between the epidemic figure in the Karnal Rural Circle and the rainfall, as registered in the Karnal Tehsil, shows that there is a fairly well-marked correlation between the amount of rain falling before the end of August and the epidemic figure for the year. September rain does not appear to have any marked effect on the amount of malaria.

TABLE I.

Epidemic figures for Karnal Rural Circle and monsoon rainfall, for the period 1916—1930.

Year.	Rainfall June—September. Inches.	Rainfall June—August. Inches.	Epidemic figures.
1916 ..	32·50	22·21	1·5
1917 ..	29·25	21·67	2·0
1918 ..	12·94	12·94	not recorded*
1919 ..	22·97	20·39	3·0
1920 ..	15·11	14·87	not available*
1921 ..	20·21	13·72	3·0
1922 ..	29·44	26·79	2·6
1923 ..	26·44	25·39	5·4
1924 ..	31·09	13·79	2·4
1925 ..	36·99	36·99	3·1
1926 ..	20·74	18·60	2·3
1927 ..	17·04	14·25	1·2
1928 ..	14·95	12·93	0·9
1929 ..	9·14	9·14	1·2
1930 ..	18·88	17·98	1·6
Average ..	22·51	18·78	2·3

**N.B.*—The epidemic figures for 1918, the year of the influenza epidemic, are not recorded. The figures for 1920 are not available.

The normal climate of Karnal District is similar to that of the greater part of the Punjab, the cold weather gradually giving way to the hot weather at the end of March, from which time it gets steadily hotter, and the relative humidity grows steadily less, till the middle of June, when great extremes of heat and dryness are normally experienced. The monsoon breaks suddenly, usually about the third week in June, with a consequent increase in the relative humidity and decrease in the maximum temperature. The minimum temperature at night remains practically unchanged at about 80°F. Periodical rain falls throughout the monsoon in the latter end of June, July and August, gradually diminishing in September, when the relative humidity again decreases. The maximum temperature shows a slight increase for a time after the cessation of the rain but gradually falls to give way to the cold weather, which commences about the middle of November.

Of the two climatic factors which control the transmission of malaria, the minimum temperature remains sufficiently high from the middle of March to the middle of November. During a large part of this time, however, the atmospheric humidity is extremely low and transmission is therefore not possible. The humidity is sometimes high for a week or two in March, after the temperature has started to rise, thus making a small spring epidemic possible, but it then decreases and does not rise again until the break of the monsoon, from which time it remains continuously high. The 8 A.M. reading is usually over 70 per cent till the monsoon ends, when it again rapidly and markedly decreases below the level at which the transmission of malaria is possible. The monsoon is therefore the sole apparent climatic controlling factor in the spread of malaria, the amount of rain falling influencing the number of breeding-places, and the associated increase in humidity, which lasts just as long and no longer than the monsoon, making it possible for the anophelines to live a long time and therefore to be capable of transmitting malaria.

In Table II the normal monsoon rainfall of Karnal, based on an average for the year 1916 to 1928, is compared with the monsoon rainfall of 1929 and 1930. It will be seen that in 1929 there was an almost complete failure of the monsoon, while in 1930, though the monsoon started in a normal manner, it stopped suddenly at the beginning of August, the total fall being nearly seven inches in defect.

TABLE II.

Monsoon rainfall, Karnal.

Month.	Normal.	1929	1930
June ..	3·0 inches.	0·11 inches.	4·23 inches.
July ..	9 6 ,,	4·87 ,,	11·25 ,,
August ..	8·0 ,,	4·16 ,,	2·50 ,,
September ..	5·0 ,,	0·00 ,,	0·90 ,,
TOTAL ..	25·6 ,,	9·14 ,,	18·88 ,,

In Tables B and C in the Appendix the weekly average temperatures and humidities are given, together with the weekly total rain for the monsoon periods of 1929 and 1930. From these it will be seen that the period of high humidity, and consequent possible transmission of malaria, lasted only six weeks to two months in either year.

As a consequence of the small rainfall in both years, and of the short period during which transmission of malaria was possible, the two years under review have been exceptionally healthy, there being extremely few cases of 'fever' in any villages in 1929, while in 1930 there were only very few cases in the majority of villages.

ENTOMOLOGICAL RESULTS.

Species caught and seasonal distribution.

From the commencement of the investigation regular collections of both adult and larval anophelines were made both in the villages visited and in the vicinity of Karnal City. The following eleven species were seen :—

A. culicifacies.
A. subpictus.
A. fuliginosus.
A. stephensi.
A. pallidus.
A. hyrcanus.
A. barbirostris.
A. maculipalpis.
A. listonii.
A. pulcherrimus.
A. maculatus.

As regards seasonal distribution, these fall into the following natural groups :—

(1) Cold weather species appearing at the end of the monsoon about the end of August or the beginning of September and continuing until May or April but very much reduced in the very cold weather, their chief preponderance being in the autumn and the spring. The species in this group are *A. fuliginosus*, *A. maculipalpis* and *A. listonii.*

(2) Warm weather and monsoon species. These commence breeding in the spring between March and May and continue to breed throughout the hot weather and the monsoon until the weather cools down with the advent of the winter. Their chief prevalence is during the monsoon period when breeding-places are most common. The species in this group are *A. culicifacies*, *A. subpictus*, *A. pulcherrimus* and probably *A. maculatus*. Of these, *A. subpictus* is far more susceptible to the effects of cold than *A. culicifacies*, starting to breed later in the year and ending earlier.

(3) Late monsoon and post-monsoon breeders starting to breed in large numbers at the end of August or the beginning of September, but disappearing at

the end of the year and not re-appearing in the spring as in the case of those species in group 1. The species in this group are *A. hyrcanus*, *A. barbirostris* and *A. pallidus*.

(4) Hot weather species. There is only one species in this group, *A. stephensi*, which breeds in large numbers from March to June and disappears at the commencement of the monsoon, though a few adults may be caught later in the year.

The seasonal distribution of the different species is illustrated in Tables D and E in the Appendix, which show the numbers of adults and larvae of each species caught in each month in terms of percentage of the total catch. As, however, a varying number of hours were spent in collecting every month it was decided to collect adults from a selected spot every week, spending the same time in collecting every time, the numbers of each species caught in different months thus being really comparable. A barrack shed in the Imperial Cattle Breeding Farm, Karnal, was chosen for this purpose and the average weekly catch for each month since the commencement of this practice in April 1930 is set out in Table III.

TABLE III.

Average weekly catch of adult anophelines made in a two hours' search in a selected locality.

Month.	*A. culicifacies.*	*A. subpictus.*	*A. fuliginosus.*	*A. stephensi.*	*A. pallidus.*	*A. hyrcanus.*	*A. barbirostris.*	*A. maculipalpis.*	*A. listonii.*	*A. pulcherrimus.*	*A. maculatus.*
April	14	0	100	1	0	0	0	0	2	0	0
May	23	0	40	1	0	0	0	0	2	0	0
June	37	8	18	4	0	0	0	0	0	1	0
July	46	73	26	3	0	0	0	0	0	1	0
August ..	42	56	71	1	1	0	0	0	0	6	0
September ..	66	41	89	3	5	4	2	1	0	5	0
October ..	15	23	61	0	3	1	0	0	1	0	0
November ..	37	31	113	0	3	1	1	0	7	1	0
December ..	19	5	40	0	2	0	0	0	13	0	0

Breeding-places.

An analysis of 902 breeding-places in which there were sufficient data available to classify them shows they may be divided as follows :—

(1) *Road-side borrow-pits.*—These are usually clear of all vegetation; they become filled with rain early in the monsoon and retain the water for several months.

The water is usually permanently discoloured and muddy. *A. subpictus* is the commonest species found (67 per cent of collections); *fuliginosus* (11 per cent), *A. stephensi* (11 per cent) and *A. hyrcanus* (11 per cent) have also been found. As *A. stephensi* only appears before the malaria season these pits may be regarded as quite harmless.

(2) *Village cattle ponds.*—Large ponds are formed near every village by the excavation of earth for house building and are used to water cattle. The banks are usually muddy with many pools beside the main pond caused by hoof prints, etc.; the water is usually discoloured and muddy and may be very foul. There is generally no vegetation on the banks, which slope gradually down into the water all round the edge. *A. subpictus* far outnumbers all other species found in these (77 per cent of collections); *A. stephensi* is occasionally present in a typical cattle pond (3 per cent). In cases where the banks are relatively steep, cattle usually use one portion of the edge only, and the other portions may be grass-grown and clean; in these cases *A. fuliginosus* (7 per cent), *A. culicifacies* (6 per cent), *A. hyrcanus* (6 per cent), and *A. barbirostris* (1 per cent) may be found. These ponds are practically harmless, the degree of danger they present varying with the amount of clean grass-grown bank present.

(3) *Dirty water drains and pools.*—This group includes the 'earth' drains at the side of roads, 'earth' house drains, pools below the outfall of these such as those in the bed of the Old Jumna Canal, the muddy streets of villages where the wastage from wells is allowed to run, dirty pools in villages, etc. These are primarily breeding-places of *A. subpictus* (77 per cent); in the early hot weather *A. stephensi* occurs in such places with fair frequency (16 per cent), while occasionally in the cleaner street drains *A. culicifacies* (5 per cent) and *A. fuliginosus* (2 per cent) may be found. Drains which are definitely dirty may be regarded as harmless.

(4) *Pools and tanks beside wells.*—These generally contain foul water, and are primarily breeding-places of *A. subpictus* (85 per cent); *A. stephensi* (11 per cent) appears during its season and rarely *A. culicifacies* (4 per cent) may be found.

(5) *Casual rain-water pools.*—This group includes only those pools on bare ground free from vegetation, which rapidly become muddy. These are *A. subpictus* breeding-places (96 per cent) with occasional *A. culicifacies* (3 per cent) and *A. fuliginosus* (1 per cent).

(6) *Ponds and swamps in grass-grown situations.*—This group includes farm tanks in which water is stored, swamps appearing at the side of roads which obstruct the natural drainage, etc. There is usually a good growth of grass at the edges, and often much floating vegetation in the water, along with reeds, etc. Though *A. subpictus* (33 per cent) is the commonest species found breeding in such places, they form very good breeding-grounds for *A. culicifacies* (27 per cent) and *A. fuliginosus* (24 per cent), while *A. stephensi* (5 per cent), *A. hyrcanus* (5 per cent), *A. pallidus* (2 per cent) and *A. pulcherrimus* (2 per cent) also occur.

(7) *Masonry tanks used for water storage.*—These have clean stone banks and a little floating vegetation. There is no grass on the edges and the water is clean.

A. culicifacies (60 per cent) is the principal species breeding in these, with *A. subpictus* (28 per cent), *A. fuliginosus* (6 per cent) and *A. barbirostris* (6 per cent). They are dangerous breeding-places.

(8) *Grassy pools.*—This group includes rain-water pools in pastures and other grassy places, and pools formed by the overflow of canals in fields. *A. fuliginosus* (36 per cent), *A. subpictus* (26 per cent) and *A. culicifacies* (19 per cent) are the chief species found in these. *A. hyrcanus* (12 per cent), *A. stephensi* (5 per cent) and *A. barbirostris* (2 per cent) also occur.

(9) *Canal seepage pools.*—At various points where the Western Jumna Canal is embanked and runs at a higher level than the surrounding land, seepage pools form below the banks. These are generally shallow grassy swamps, usually not more than one foot deep. On account of the intermittent running of the canal, and consequent periodical drying out of these pools, they mostly contain a growth of grass only, though in some of the deeper and more permanent pools and swamps aquatic vegetation is present. They provide prolific breeding-places for most of the species of mosquitoes present in the area, the only species which have not been recovered from them being *A. listonii* and *A. maculatus*, the other species occurring in about equal numbers. They may be regarded as dangerous breeding-places.

(10) *Canals, canal distributaries, and running ditches.*—The main Western Jumna Canal is only rarely found to contain mosquito larvae, but the numerous distributaries which it gives off, which are usually grass-grown, with ragged edges, and contain slowly running water, form excellent breeding-grounds for *A. culicifacies* (45 per cent); *A. subpictus* breeds in these (20 per cent) with *A. fuliginosus* (11 per cent); they form the preferential breeding-grounds for *A. barbirostris* (11 per cent) and *A. hyrcanus* (9 per cent), while *A. stephensi*, *A. listonii* and *A. maculatus* are occasionally found in them. These are the most dangerous breeding-grounds seen in the area, and it is worthy of note that the main road of the Civil Lines in Karnal itself, where the majority of the officials live, has an irrigation ditch on either side of the road, from which *A. culicifacies* larvae may be recovered in large numbers at any time in the hot weather and monsoon.

(11) *Wells.*—The majority of the wells examined proved to contain no anopheline larvae, but the following species were recovered from others:—*A. subpictus* (35 per cent), *A. stephensi* (19 per cent), *A. culicifacies* (22 per cent), *A. listonii* (11 per cent), *A. barbirostris* (11 per cent) and *A. hyrcanus* (3 per cent). It was noted that the wells in the centre of a village, in constant use, and wells from which water was regularly drawn by the Persian Wheel or 'Charsa' system, rarely contained anopheline larvae, the majority of the larval finds being from unused or little used wells. The wells from which *A. barbirostris* and *A. hyrcanus* were recovered were in the centre of flooded rice fields, the water level in the well being within a few feet of the surface. In view of the fact that *A. stephensi* was not found breeding at all during the malaria season, and that it was thought that *A. culicifacies* only bred in these wells when its normal breeding-grounds had dried up, it may be concluded that the ordinary village well is harmless, though disused

and abandoned wells form a source of danger and should be either filled in or covered over.

(12) *Rice fields.*—When flooded these form preferential breeding-grounds for *A. hyrcanus,* which may be almost always recovered from them, together with *A. subpictus* and *A. fuliginosus. A. culicifacies, A. barbirostris* and *A. pulcherrimus* have been found in the pools left in these fields after the greater part of the water has been run off.

Relative importance as malaria carriers of the anophelines found in the area.

Of the eleven species of anophelines seen in this area three, *A. culicifacies, A. stephensi,* and *A. listonii,* are considered as dangerous carriers by Covell (1927). *A. maculatus* is considered as a dangerous carrier in the Malay States, though the recent work of Ramsay (1930) suggests that it is not of great importance in India. Covell considers that insufficient work has been done on *A. maculipalpis* and it is consequently impossible to be certain of its importance, while he is definitely of the opinion that the other species here seen are not of great importance in the transmission of malaria in India.

It was not possible to carry out a long series of dissections at the same time as the village examinations were made, but a series of dissections was made by Dr. K. L. Chowdhury in September 1930 in Indri, summarized in Table IV. At the time these dissections were made the monsoon had ceased, and the atmospheric humidity was in marked defect, the consequent shortening of the average life of the mosquito being the probable reason that oöcysts only, and not sporozoites, were found, no mosquitoes living sufficiently long to develop gland infections. The results would appear to show, however, that *A. culicifacies, A. listonii,* and possibly *A. maculipalpis,* are readily infected with malaria, and that *A. fuliginosus* may be infected but in small numbers, as has been remarked by Covell. Of the other two possibly important species, *A. stephensi* was not found in sufficient numbers to enable conclusions to be drawn, and *A. maculatus* was not found at all during Dr. Chowdhury's survey.

As regards the relative importance in Karnal of these species, it is considered that *A. culicifacies* is the one really important carrier influencing the severity of malaria in the district, it having been repeatedly found infected in nature in India, and occurring in large numbers at that time of year when most of the transmission of malaria is taking place, and always being found breeding in close proximity to any village showing epidemic signs. *A. stephensi* is not considered to be of any practical importance in this area, it being never present except in very small numbers, and only being found breeding in the early hot weather, before the transmission of malaria is possible. *A. listonii* is possibly of subsidiary importance to *A. culicifacies* towards the end of the malaria season, though the small numbers in which it is usually seen and the fact that its period of greatest prevalence is in the cold weather, breeding only starting at the end of the malaria season, prevent it taking a large part in the inauguration of an epidemic. *A. maculatus* is definitely considered to

be of no importance whatever in this district, on account of its small numbers and its relative innocuousness in India, as shown by Ramsay. The position of *A. maculipalpis* is not certain, but it is probable that on account of its usual scarcity and seasonal distribution similar to that of *A. listonii*, it is of very minor importance.

TABLE IV.

Results of the dissection of anophelines in Indri, Karnal, by Dr. K. L. Chowdhury.

Species.	Number dissected.	Gut infections.	Gland infections.	Percentage infected.
A. fuliginosus ..	200	1	0	0·5
A. culicifacies ..	152	15	0	9·8
A. listonii ..	24	2	0	8·3
A. maculipalpis ..	26	1	0	3·8
A. pallidus ..	7	0	0	0
A. pulcherrimus ..	8	0	0	0
A. stephensi ..	3	0	0	0
A. hyrcanus ..	2	0	0	0

N.B.—All the mosquitoes dissected were over one week old, as determined by the condition of the ovaries.

FACTORS INFLUENCING THE SEVERITY OF MALARIA IN THE DIFFERENT VILLAGES.

In years in which the rainfall is normal, or subnormal, as in the year under review, there seem to be two factors influencing the severity of the malaria in the villages examined; the proximity of the breeding-places of *A. culicifacies*, and the severity of the last autumnal epidemic.

As will have been realized from the discussion of the different types of breeding-places seen and the species of anophelines found to be breeding in them, it is extremely rare to find *A. culicifacies* actually breeding within the limits of a village. The village well generally contains no dangerous species during the malaria season, nor does the trough or the pools at its side or the muddy drains in the village streets, and on the few occasions when this species was found to be breeding in such places it was present in such small numbers as to be negligible. The normal village cattle pond, with its shallow bare edges, and the hoof prints at its side, is also harmless. The commonest dangerous breeding-places to be found near a village are the canal distributaries, or grassy drains containing slowly moving clean water, and swamps or ponds which, unlike the usual cattle pond, contain clean water with a fair amount of vegetation, or with grassy banks. If there is a canal distributary in which *A. culicifacies* may breed, or the empty bed of which holds a series of pools, or which

overflows its banks and forms a series of grassy pools at its side, or if there is an extensive clean swamp with grassy edges and containing vegetation, within a quarter of a mile of the village, then the spleen rate of the village will be relatively high. and even in years when the rainfall is markedly deficient there will be a slight autumnal outbreak of malaria. In the absence of any of these conditions it is highly probable that the spleen rates will be low and that in years of subnormal rain there will be little autumnal malaria.

In years of excessive rain it is probable that the level of the subsoil water is the factor controlling the numbers of breeding-places for *A. culicifacies* because the heavy early rain will saturate the soil, and prevent subsequent rain from sinking into it, with consequent excessive pool formation of the type that forms suitable breeding-places for *A. culicifacies*. The saturation of the soil will also tend to increase the malaria by maintaining a high atmospheric humidity and favouring an increased length of life of the carrier species.

It does not appear from our examinations that the type of irrigation used, with canal or well water, need affect the intensity of malaria in a village. A village surrounded by land irrigated from the canal is not unusually malarious if no distributary passes near to the village itself, and if excessive irrigation, which would tend to raise the subsoil water level, is not employed.

The second factor influencing the severity of malaria in a village in such abnormal years as those under review is the severity of the previous autumnal epidemic. The phenomenon of *post-epidemic hyperendemicity* is well known, and just as any exceptionally severe epidemic is followed by several years in which the usual autumnal epidemic is greater than normal, any village which, on account of its disadvantageous position has normally been subject to severe malaria, will continue to be worse than the neighbouring villages for some years after the locality has been improved by the drainage of the swamp or other cause of its previous ill health. This is presumably due to the greater number of gametocyte carriers in the village providing a readier means of infection for the reduced numbers of dangerous anophelines than in the neighbouring villages which were not previously unduly unhealthy, and would seem to indicate the advisability of accompanying any drainage operations around a village by intensive treatment of the inhabitants, or at any rate of all fever cases, if it is desired to obtain immediate full advantage of the drainage operations.

The influence of the above two factors is well shown in the following brief descriptions of the conditions of the villages surveyed:

(1) **Indri.**—Spleen rate at successive examinations, 55, 48, 54. 83, 72, 62, 66, 68, 63, 65, 51, 80, 75, 86. Total for all examinations, 66 per cent. Irrigation from wells. This village is situated in waterlogged ground within six hundred yards of the main Western Jumna Canal. The Budha Khera Escape, a wide shallow channel containing either running water or a series of pools in which *A. culicifacies* breeds in large numbers, runs within fifty yards of the village. There are numerous grassy pools on either side of the Escape during the monsoon, and there is a permanent grassy jheel about four hundred yards from the village. *A. culicifacies* can be

found in large numbers in the houses and cattle sheds from April to November, whilst *A. listonii* and *A. maculipalpis* are fairly numerous from September till April. It is the most malarious of the villages examined, and this is ascribed to the proximity of the Budha Khera Escape, and the waterlogged condition of the soil favouring the appearance of many grassy pools early in the monsoon.

(2) **Taraori.**—Spleen rate at successive examinations. 30, 20, 23, 43, 56. Total for all examinations, 39 per cent. Irrigation is from wells. This village is within four hundred yards of the Rakshi Channel, a combined drain and irrigation channel holding clear running water and with grassy banks, in which *A. culicifacies* has been found breeding; to the west of the village there is a very extensive tank containing a certain amount of aquatic vegetation and with grass-grown banks, in which also *A. culicifacies* breeds. Adults of this species were found in fair numbers in September 1930.

This village had little, if any, malaria in 1929, and had a quite considerable epidemic in 1930. It is probable that the Rakshi Channel, on account of its distance is of less importance than the extensive tanks to the west; on account of the almost entire absence of rain in 1929 these partially dried up and resembled ordinary village cattle ponds, breeding no dangerous species. In 1930, when the rainfall was double that in the previous year, though still in defect, they overflowed their grassy banks slightly with the production of excellent breeding-grounds, with the consequent appearance of considerable malaria.

(3) **Munak.**—Spleen rate at successive examinations, 29, 42, 43. Total for all examinations 39 per cent. Irrigation in this village is by canal water. The village is built on a small knoll in low-lying land about eight hundred yards from the Western Jumna Canal. The surrounding country is partially waterlogged, there being extensive marshes about half a mile away. There is a canal distributary alongside the main canal about six hundred yards away, in which *A. culicifacies* has been found breeding. The village is surrounded by a number of large ponds. A large pond to the west of the village which contains reeds and grass in parts, and a wide grass-grown drain both act as breeding-grounds for this species, the adults of which are fairly numerous in the houses in September. It is interesting to note here that *A. maculipalpis*, which breeds freely in the swamp half a mile away and the adults of which can be found in large numbers in a house some six hundred yards from the village, was only found once in this village out of a total of 241 anophelines collected, thus indicating that its range of flight is small. The dangerous breeding-ground near this village is probably the pond immediately to the west of it, and the drain to this pond, the canal distributary six hundred yards away being of little importance on account of its distance. The spleen rate is above normal for this area, and there was a slight outbreak of malaria in October 1930.

(4) **Kalwaheri.**—Spleen rate, 39 per cent. Irrigation in this village is from wells. It is a small village near the Budha Khera Escape, referred to in connection with Indri. It was only visited once when the spleen rate among 18 children was 39 per cent.

(5) **Budha Khera.**—Spleen rate, 37 per cent. Irrigation is by canal water. The village is on the bank of the Budha Khera Escape, previously referred to. It was only visited once when the spleen rate of 16 children was 37 per cent.

(6) **Shahpur.**—Successive spleen rates, 56, 32, 24, 36, 33. Total for all examinations, 35. Irrigation is by canal water. A small village built on the bank of a canal distributary of medium size, and surrounded in the monsoon by a series of ponds, one of which is suitable for *A. culicifacies*, the adults of which were numerous in the village in September 1930. There is also at times a certain amount of seepage beside the canal bank. Malaria is of moderate severity with a slight outbreak in the autumn of 1930.

(7) **Ghogripur.**—Successive spleen rates, 39, 33, 17, 49, 44. Total for all examinations, 32 per cent. Irrigation is from wells. The village is about three hundred yards from the Western Jumna Canal, there being between the canal and the village a branch canal which normally slightly overflows its banks, with the production of a series of grassy pools. *A. culicifacies* has been found breeding in these. Between the branch canal and the village there is a deep depression which becomes filled with water in the monsoon, and forms what would appear to be a good breeding-place for *A. culicifacies*, though this species has not been recovered from it by us. A moderate outbreak of malaria occurred in the autumn of 1930, *A. culicifacies* being recovered from the houses. It is probable that the pools at the side of the small canal serve as the important source of anophelines.

(8) **Kambohpura.**—Successive spleen rates, 42, 34, 19, 25, 22, 21, 20, 21, 15, 25, 25, 55, 60. Total for all examinations, 30 per cent. Irrigation is from wells. This village is built on a mound at the side of a low-lying stretch of land, once covered by water forming a swamp which has now been completely drained. Round the village at present there are the usual cattle ponds with muddy shallow banks, which appear to be unsuitable as breeding-places for *A. culicifacies* which has not been found despite repeated and careful search There are no canal distributaries near the village. About six hundred yards away *A. culicifacies* has been found breeding in some pools in rice fields. Adult *A. culicifacies* are at all times rare in the village, only 16 being found out of 379 mosquitoes collected in the hot weather and monsoon. The only other possible carriers seen in the village are *A. stephensi*, of which eight specimens only have been caught, and *A. listonii*, of which one specimen has been caught. Despite the relative scarcity of dangerous breeding-places near to the village and the scarcity of adult anopheline carriers in the village the malaria here is quite considerable, there being small epidemics in the autumn of 1929 and 1930, when the spleen rate reached 60 per cent. It is thought that this is an example of the post-epidemic hyperendemicity previously referred to, the village having been very unhealthy until the swamp beside it was drained four years ago. The suggestion that the mechanism by which the greater severity of malaria is kept up, despite the scarcity of carrier anophelines, is that an unduly high percentage of the population are gametocyte carriers and capable of infecting the few anophelines

present, is borne out by the fact that in August 1929, before the commencement of the slight epidemic, five out of forty-eight children examined, or 10 per cent, were found to have crescents in the peripheral blood, an exceptionally high figure for the pre-epidemic period, and that crescents have always been more numerous in this village than in other villages in the same district.

(9) **Barauta.**—Successive spleen rates, 42, 38, 17, 27, 22. Total for all examinations, 29 per cent. Irrigation is partly from wells and partly with canal water. This village is about seven hundred yards from the main Western Jumna Canal, at the side of which there is a considerable amount of seepage water, forming swamps in which, amongst other species, *A. culicifacies*, *A. stephensi* and *A. maculipalpis* breed. There are the usual muddy cattle ponds around the village, and a very small terminal canal distributary ends near the village. Adults of *A. culicifacies* have never been very numerous in the village. Though the spleen rate was high when this village was first examined in June 1929, it has since markedly decreased, except for a slight rise in September 1930. It is probable that the seepage areas beside the canal are the chief source of dangerous anophelines in this village, and that in years of normal or excessive rainfall these are sufficiently augmented by rain to approach within dangerous proximity of the village, thus accounting for the original high spleen rate. In years of deficient rainfall these are too far from the village to have any serious effects.

(10) **Dadupur.**—Successive spleen rates, 35, 37, 28, 25, 19. Total for all examinations, 27 per cent. Irrigation around this village is by canal. The village is on a small mound in low land, and in the monsoon is almost surrounded by a series of large ponds, which on the whole have the usual character of village cattle ponds, with muddy shallow banks, though there are small stretches of the edges suitable for *A. culicifacies*, which has been twice found breeding in them. Adults of this species are at all times few in the village, only 13 being found out of a total of 267 anophelines caught in the hot weather and monsoon. There is a very small terminal canal distributary 200 yards north of the village, which is not considered as an important breeding-place. There was no sign of any autumn epidemic in this village in 1930, the spleen and parasite rates both steadily diminishing in August, September and October. It is probable that such malaria as exists is transmitted by *A. culicifacies* breeding in the village ponds, which are practically harmless in such years as those under review, but which in years of excessive rain will overflow their banks to a greater extent and form extensive grassy pools.

(11) **Singhoa.**—Successive spleen rates, 17, 27. Total for all examinations, 25 per cent. Irrigation by wells. This village lies on an eminence two hundred yards from the Budha Khera Escape, previously referred to, while between the village and the Escape there runs a grassy drain built to drain the Samorha Jheel some miles away. *A. culicifacies* breeds in both these drains and in the Escape, while adults are relatively numerous in the houses. The two examinations of this village were made in May 1929 and at the beginning of September 1930, on which latter occasion there was a certain amount of malaria in the village. It is probable that if

the examinations had been made at a later date more malaria would have been found, and the spleen rate would have been considerably higher.

(12) **Dadupur Ranghran.**—Spleen rate, 24 per cent. Irrigation by wells. This village was visited once only, in May 1929, when there was no water of any sort near the village, the nearest well being two hundred yards away. The spleen and parasite rates were low and it appeared to be healthy.

(13) **Gagsina.**—Successive spleen rates, 17, 23, 22. Total for all examinations, 21 per cent. Irrigation by canal water. This small town lies in flat land a mile away from the main canal; it is surrounded by the usual foul ponds, and there is a canal distributary half a mile away. Malaria is slight, there being no epidemic in either 1929 or 1930. It is probable that the canal distributary is too far away to have any important effect, while the ponds are unsuitable for *A. culicifacies*, which has never been found breeding in them.

(14) **Shamgarh.**—Successive spleen rates, 26, 11, 23, 21. Total for all examinations, 20 per cent. Irrigation from wells. This village is built on an eminence in the usual flat land, being surrounded in the monsoon by the usual muddy ponds with shallow edges bare of vegetation. About half a mile away from the village, where the natural drainage of the land has been obstructed by the Grand Trunk Road, there is a semi-permanent swamp, overgrown with reeds and other vegetation, in which *A. culicifacies* breeds. This species has also been found breeding in very small numbers in a muddy drain beside a well in the village. Adult *A. culicifacies* have never been numerous in the village. Malaria here is very slight, there being very little in the autumn of 1930. The swamp beside the Grand Trunk Road is too far distant to have any marked effect on the village; the cattle ponds do not breed any dangerous species, while the occasional *A. culicifacies* breeding in muddy drains in the village are so few as to be harmless.

(15) **Padhana.**—Successive spleen rates, 18, 12. Total for all examinations, 15 per cent. Irrigation by wells. This village was visited twice, in May and August 1929; there were no ponds or other standing water near the village, and no irrigation channels or drains within a mile of the village. The spleen and parasite rates were low and it would appear to be a healthy village.

(16) **Kunjpura.**—Successive spleen rates, 20, 25, 18, 19, 17, 15, 15, 15, 27, 18, 8. Total for all examinations, 17 per cent. Irrigation from wells. This village lies in flat land in which the subsoil water is at a very high level, with the consequent formation of numerous weed-grown grassy swamps, the nearest of which is four hundred yards from the village. *A. culicifacies* has been found breeding in these, but adults of this species are normally difficult to find in the town. Malaria here is very slight, there being no autumnal rise either in 1929 or 1930. It is probable that the jheels are too distant from the town to affect it seriously.

(17) **Darar.**—Successive spleen rates, 30, 19, 10, 17, 16, 16, 14, 12, 13, 18, 8, 10, 13. Total for all examinations, 15 per cent. Irrigation by wells. This village stands on a knoll in flat dry land; on its borders there are three cattle ponds, always foul, with shallow banks and no vegetation, in which no dangerous species has ever

been found breeding, and there is normally no other water near the village. *A. culicifacies* has always been very difficult to find within the village, except on one occasion, when eleven specimens were found out of a total catch of 123 anophelines; on this occasion careful search failed to find the breeding-place of these, and it was presumed that they had bred in a grassy pool which had formed near the village after heavy rain, but had dried up at the time of our visit. This is one of the least malarious villages examined, there being no sign of any epidemic either in 1929 or in 1930. It is possible that in years of heavy rain, and partial waterlogging of the soil, grassy pools may form in abundance around the village, forming breeding-grounds for *A. culicifacies*, with a consequent epidemic.

(18) **Rambha.**—Successive spleen rates, 17, 14, 4. Total for all examinations, 12 per cent. Irrigation from wells. Rhamba is approximately a mile away from the Western Jumna Canal, and has around it in the monsoon extensive shallow muddy ponds bare of vegetation, in which no dangerous species breed. There are no canal branches or other suitable breeding-places for *A. culicifacies* near the village, and adults of this species are very rare in the houses, only 2 being found out of a total catch of 199 anophelines during the hot weather and monsoon. It is the healthiest village seen and showed no sign of any epidemic either in 1929 or 1930.

THE WEEKLY EXAMINATION OF A SINGLE VILLAGE.

The village selected for the weekly examination, previously described as the first part of the intensive examination, was Kunjpura. This is a backward village in low-lying *Khadir* land about eight miles from Karnal. The people are poor, the surrounding land is sandy and infertile, and the subsoil water is within five or six feet of the ground except actually within the village, which is on a slight eminence. The irrigation of the fields is from shallow wells. A series of swamps near the town mark the bed of an old branch of the river Jumna. In years when the Jumna floods badly a branch is said to come down this course still, and when it overflows its banks the flood water may come up to the walls of the village. The spleen rate on first examination was relatively low, 20 per cent. The village thus presents all the factors which should render it liable to a severe epidemic in years of excessive rainfall, as outlined by Christophers (1911) and Gill (1928); the immunity of the population is low, as shown by the low spleen rate; the nutrition of the villagers is below the average for the Karnal District, as they live in an infertile sandy district; and, on account of the high subsoil water and the liability to flooding, there should be a great increase in the atmospheric humidity and in the number of suitable breeding-places for anophelines in years of excessive rain.

Kunjpura was first visited in May 1929, and next on the 25th of June 1929, from which date it was examined weekly until the 12th of September 1929, when examinations had to be stopped on account of the pressure of other work. The examination was carried out each week on as nearly as possible the same series of children, the schoolmaster giving us valuable assistance, and was the same every week, except that for the first three weeks in July the children were not examined

for enlargement of the spleen, because it was then thought only necessary to do monthly examinations as the spleen changes its size relatively slowly. On and after the fourth examination in July, however, it was decided to abandon this procedure, and to examine the children for splenic enlargement every week. Collections of adult mosquitoes and larvae were made in and around the village on every occasion.

The anopheline collections during this period revealed *A. subpictus*, *A. culicifacies*, *A. stephensi* and *A. pulcherrimus*, the different numbers of each species which were found on each examination being shown in Table V.

TABLE V.

Numbers and species of adult anophelines recovered from Kunjpura during the monsoon period, 1929.

Date.	*A. subpictus.*		*A. culicifacies.*		*A. stephensi.*		*A. pulcherrimus.*	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
25-5-29 ..	1	2	0	0	0	0	0	0
25-6-29 ..	0	0	1	0	0	0	0	0
2-7-29 ..	0	16	0	0	0	0	0	0
8-7-29 ..	1	21	0	0	1	1	0	0
16-7-29 ..	1	15	0	0	0	1	0	0
23-7-29 ..	1	13	0	0	0	0	0	0
30-7-29 ..	3	20	0	2	0	0	0	0
6-8-29 ..	0	16	0	1	0	0	0	0
13-8-29 ..	3	21	0	4	0	1	0	0
21-8-29 ..	2	27	0	1	0	0	0	0
5-9-29 ..	4	13	0	4	0	0	0	0
16-9-29 ..	6	13	0	2	0	0	0	1

A. subpictus was commonly found breeding in the pools and tanks beside wells, the muddy drains of streets, casual collections of rain water, and in the swamps some way from the town. *A. culicifacies* was found breeding in these swamps which are at no place nearer than quarter of a mile from the town, and are mostly half a mile or more away; in a disused well, and in a collection of water near a well, both of these last being breeding-places of very minor importance.

The picture shown by the repeated examinations of bloods and spleens was that of an almost complete absence of active malaria such as might be produced by reinfection during the period when the survey was made. The results are given in Tables VI and VII. Of 711 blood films examined during this monsoon period, only one showed what might be an acute infection, 2,000 benign tertian parasites per c.mm., only two others showed more than 100 parasites per c.mm., while the

remaining positive films showed very low parasite counts such as are associated with very old infections. The parasite rate never rose above 7 per cent. The spleen rate remained practically steady at 15 to 20 per cent, except for one week in which it rose to 27 per cent, a finding which is believed to be due to the error resultant on examining small samples, as it was not accompanied by any rise in the parasite rate, or by any complaint of fever. Table VI shows the results of the spleen and blood examinations in this village for the period described above, and also for one examination in August 1930, when the spleen rate was found to be exceptionally low; this was believed to be due partly to the natural reduction in the absence of active malaria, and partly due to the fact that the village schoolmaster was administering quinine freely to his boys as a result of enthusiasm aroused by our visits during the previous monsoon.

TABLE VI.

Results of blood and spleen examinations in Kunjpura from May 1929 *to October* 1930.

Date.	SPLEENS.				BLOODS.						
	No. exd.	No. pos.	Rate per cent.	*A. U. cm.	No. exd.	M. T.	B. T.	Q.	Mixed.	Total.	Rate per cent.
25-5-29	52	10	20	10·5	52	1	1	0	0	2	4
25-6-29	53	13	25	9·8	53	1	0	0	0	1	2
2-7-29	..	..	..	..	62	2	1	0	0	3	5
9-7-29	..	..	..	..	53	2	0	1	0	3	6
16-7-29	..	..	..	..	49	0	0	0	0	0	..
23-7-29	55	10	18	9·2	55	4	0	0	0	4	7
30-7-29	62	12	19	9·2	62	1	0	0	0	1	2
6-8-29	54	9	17	8·5	54	1	0	0	0	1	2
13-8-29	74	11	15	11·0	74	4	1	0	0	5	7
21-8-29	55	8	15	9·6	55	4	0	0	0	4	7
29-8-29	60	9	15	11·2	60	2	0	0	0	2	3
5-9-29	71	19	27	9·2	71	3	0	0	0	3	4
12-9-29	71	13	18	8·9	71	2	0	0	0	2	3
27-8-30	88	7	8	10·1	88	1	4	0	0	5	6
TOTAL ..	695	121	17	..	799	28	7	1	0	36	4

* A. U. signifies 'Average Apex-Umbilicus Measurement.'

The parasite counts encountered amongst the children from this village, during the monsoon of 1929, are shown in Table VII.

TABLE VII.

Numerical values of the parasite counts seen in Kunjpura during 1929.

Species.	Number with a parasite count, per c.mm. of					Total.
	Over 5,000	1,001–5,000	501–1,000	101–500	Under 100	
P. falciparum	0	0	0	2	25	27
P. vivax	0	1	0	0	2	3
P. malariae	0	0	0	0	1	1

In the case of sixty-nine children who were seen on five or more occasions, their attendances were sufficiently regularly spaced to give a reliable history for the whole period. Of these sixty-nine, fifteen had an enlarged spleen when first examined; in five of these the spleen had become impalpable at the end of the period, the size of the spleen remaining practically unchanged in the others Of the fifty-four in this group in whom the spleen was not palpable at the first examintion, five had an enlarged spleen at one time or another, though in three of these the enlargement was purely transitory, disappearing before the last examination.

A possibility of error in this series is that children might absent themselves from the school, where the examinations were carried out on account of malaria. We do not believe that this had any material effect on the results, because we have observed that in other villages, when there is malaria in the village, children attend school with signs of active malaria, as shown by infection of the peripheral blood with large numbers of parasites, and enlarged spleens. There was a considerable amount of absenteeism from this school, as from all rural schools in this area, due to the necessity for the children of an agricultural community to help their parents in the fields for a part of the week. It was impossible to 'follow up' such children because they were not to be found in their homes, but in the fields.

THE MONTHLY EXAMINATION OF THREE VILLAGES.

This was undertaken with the idea of obtaining a picture of the malaria throughout the year in villages which seemed, from the early examinations to be the most malarious, the average, and the least malarious in the district. The villages chosen were Indri, as the most malarious, with a spleen rate on first examination of 55 per cent; Kambohpura as the average village, with a spleen rate of 42 per cent; while Darar, with a spleen rate of 30 per cent, was chosen as the least malarious of those examined. The examinations were carried out as regularly as possible, but unavoidable absence from Karnal and pressure of other work made absolute regularity impossible; in the case of Indri, fourteen, and in the other villages, thirteen, examinations were made between May 1929 and October 1930.

Indri.

This small village, some seventeen miles north of Karnal, was some four hundred yards from the Western Jumna Canal when it was visited by Baker and Dempster in 1846. At their examination they found that the spleen rate amongst children was 75 per cent, the spleen rate in adults 45 per cent and the depth of the subsoil water below the ground 15 feet. When the canal was re-aligned in 1885 this channel was closed, the new canal running some six hundred yards from the village, and the old canal was used as a drainage line. In 1890 a large branch canal, the Sirsa Branch, was taken off the other side of the canal at Indri, which necessitated the building of a regulator in the main canal, with consequent blocking back of the water in the canal above Indri and associated waterlogging of the surrounding land. When this regulator in the main canal was built the disposal of excess water became an important problem, and this was discharged down the Budha Khera Escape, which follows the line of the Old Western Jumna Canal with minor exceptions, one of these being that it flows within fifty yards of Indri, instead of four hundred yards away, as did the old canal. At this time Indri was a small town with a population of about 5,000, but from then onwards it has decreased in size and in importance till it is now a village of some five or six hundred population only. The decrease is ascribed by the villagers to the unhealthy nature of the locality producing a natural decrease in the population, and to migration of the inhabitants on account of the decreased fertility of the soil due to deposition of mineral salts (*reh*), in the upper layers of the soil which normally follows waterlogging.

At the present time the village lies a few yards from the Budha Khera Escape, which contains either shallow running water or else a series of pools, in which numerous *A. culicifacies* breed for the greater part of the monsoon period. On the far side of the Escape, and some five to six hundred yards from the village, are large swamps due to seepage from the main canal; there is a large grassy pond some four hundred yards to the west of the village where natural drainage has been interfered with by a road, and to the south of the village, in the monsoon, there are a number of shallow muddy ponds. Irrigation is from wells only and the subsoil water is ten feet below ground level in the dry weather, rising to about six feet in the wet season.

The adult anophelines collected from this village were *A. subpictus*, *A. culicifacies*, *A. fuliginosus* *A. stephensi*, *A. pallidus*, *A. maculipalpis*, *A. listoni*, and *A. pulcherrimus*. The numbers of each species recovered on each of the seventeen days when collections were made are shown in Table VIII (on some occasions, collections were made on other dates than those of the official examinations). The chief breeding-place for *A. culicifacies* was the Escape, either when running or when containing a series of pools in its bed, larvae of this species being found there on many occasions, and once in the grassy pond some way from the village. There is no doubt that the Escape is the only really important breeding-place of this species in the vicinity.

TABLE VIII.

Number and species of adult anophelines recovered from Indri, May 1929 *to October* 1930.

Date.	*A. subpictus.*		*A. culicifacies.*		*A. fuliginosus.*		*A. stephensi.*		*A. pallidus.*		*A. maculipalpis.*		*A. listonii.*		*A. pulcherrimus.*	
	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.
30-5-29 ..	2	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
11-7-29 ..	16	1	7	0	1	0	0	0	0	0	1	0	0	0	0	0
17-8-29 ..	11	0	10	0	10	2	1	0	0	0	0	0	0	0	0	0
23-9-29 ..	6	2	14	1	20	0	0	0	0	0	3	0	0	0	4	0
8-10-29 ..	7	1	2	1	3	0	0	0	0	0	1	0	4	0	0	0
26-11-29 ..	7	0	1	0	22	0	0	0	0	0	0	0	2	0	0	0
16-12-29 ..	0	0	0	0	0	0	2	0	0	0	4	0	12	0	0	0
20-1-30 ..	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0
19-2-30 ..	0	0	0	0	4	0	0	0	0	0	5	0	3	0	0	0
8-3-30 ..	0	0	0	0	25	0	0	0	0	0	26	0	30	0	0	0
17-3-30 ..	0	0	0	0	66	1	3	1	0	0	7	0	9	0	1	0
27-3-30 ..	0	0	1	0	46	1	22	1	0	0	12	0	16	0	0	0
30-4-30 ..	0	0	5	0	45	2	36	7	0	0	0	0	10	1	0	0
4-8-30 ..	41	4	4	0	2	0	3	0	0	0	1	0	0	0	0	0
4-9-30 ..	31	7	23	4	90	0	1	0	1	0	1	0	2	0	5	0
20-10-30 ..	54	4	3	0	28	1	0	0	3	0	1	0	0	0	0	0

The findings from the repeated blood and spleen examinations, the results of which are set out in Table IX, show that the village undoubtedly had a small epidemic both in 1929 and 1930, the spleen rate, though continuously high, showing wave-like variations, with a rapid and marked increase in September, associated with an increase in the parasite rate, followed by a steady gradual decline until August in the next year, when the previous rise was repeated. It will be noted that in both years the parasite rate started to increase before any increase was seen in the spleen rate, and that the increase in the spleen rate is associated with an increase in the average size of the spleen, as shown by a decrease in the apex-umbilicus (A. U.) measurement. Though there was a slight increase in the number

of positive films in April 1930, this was insufficient to be regarded as a Spring epidemic. The majority of positive blood films were due to *P. falciparum,* which at all times predominated over *P. vivax* except in August 1930, there being some suggestion that the early part of the epidemic was due to this species.

TABLE IX.

Results of blood and spleen examinations in Indri from May 1929 *to November* 1930.

Date.	SPLEENS.				BLOODS.						
	No. exd.	No. pos.	Rate per cent	A. U. cm.	No. exd.	M. T.	B T.	Q.	Mixed.	Total.	Rate per cent.
30–5–29	60	33	55	8·3	60	4	1	1	0	6	10
11–7–29	54	26	48	7·9	54	4	0	2	0	6	11
17–8–29	54	29	54	8·0	54	4	6	2	0	12	22
23–9–29	42	35	83	7·0	42	9	5	0	0	14	33
26–11–29	57	41	72	7·2	57	10	3	0	1	14	24
16–12–29	74	46	62	7·8	74	16	5	1	1	23	31
20–1–30	53	35	66	7·8	53	14	2	0	0	16	30
19–2–30	60	41	68	8·5	60	5	1	4	0	10	17
17–3–30	75	47	63	8·3	75	3	0	0	0	3	4
30–4–30	69	45	65	7·9	69	9	3	1	0	13	19
4–8–30	68	35	51	7·9	68	1	6	0	0	7	10
3–9–30	71	57	80	7·1	71	12	9	0	0	21	30
18–9–30	48	36	75	6·7	48	4	4	4	0	12	25
20–10–30	58	50	86	6·3	58	18	0	0	0	18	31
TOTAL ..	843	556	66	..	843	113	45	15	2	175	21

We believe that in years of subnormal rainfall, such as those in which these examinations were carried out, the chief source of dangerous anophelines in this village is the neighbouring Escape, and that the malaria is kept at a high level even in years of low rainfall by the phenomenon of post-epidemic hyperendemicity, keeping the number of relapsing carriers higher than in other villages. In years of excessive rain, or possibly in normal years, it is probable that on account of the waterlogged condition of the surrounding ground, large numbers of grassy pools are formed and remain throughout the latter end of the monsoon, forming good breeding-grounds for *A. culicifacies*.

The numerical values of the parasite counts seen amongst these children under ten years of age in Indri are given in Table X ; it will be noted that the higher parasite counts, denoting active malaria, are much more common in this village than in others.

TABLE X.

Numerical values of the parasite counts seen in Indri.

Species.	Number with a parasite count, per c.mm. of					Total.
	Over 5,000	1,001–5,000	501–1,000	101–500	Under 100	
*P. falciparum**	13	11	7	29	53	113
P. vivax	2	8	1	17	17	45
P. malariae	0	2	2	6	5	15
Mixed *P. vivax*† and *P. falciparum*.	0	1	0	1	0	2

* These figures include 17 cases in which crescents were seen.
† These figures include one case in which crescents were seen.

The spleen frequency curves for each examination, details of which are given in Table XI, show a great tendency to be bimodal, the relative importance of the different modes, as well as their positions, varying with the seasons. During the period of active malaria, as shown in the figures for September 1929 and 1930, small spleens with an A. U. measurement of 10 cm. or more are few in number, spleens projecting to within 8 cm. being the rule. At the end of the malaria season, exemplified in the figures for November 1929 and October 1930, still larger spleens projecting to within 5 cm. of the umbilicus are common. When the malaria season is completely over, these large spleens gradually decrease in size, the mode at 5 cm. ceasing to be of any importance, and the spleens congregating round either 8 cm. or 10 cm. from the umbilicus. This is associated with a decrease in the average apex-umbilicus measurement (A. U. in Table IX) and in the spleen rate as a whole.

TABLE XI.

Frequency of the different sizes of spleen in Indri at each examination.

Apex-Umbilicus Measurement.	Number with this sized spleen.													
	30-5-29.	11-7-29.	17-8-29.	23-9-29.	24-11-29.	16-12-29.	20-1-30.	19-2-30.	17-3-30.	30-4-30.	4-8-30.	3-9-30.	18-9-30.	20-10-30.
cm.														
15 ..	0	0	0	0	0	0	0	0	1	0	0	0	0	0
14 ..	1	0	0	1	0	1	0	0	0	1	0	0	0	0
13 ..	0	0	3	0	0	2	1	3	1	1	0	1	0	0
12 ..	2	1	0	1	3	3	2	2	2	2	2	2	2	1
11 ..	4	4	0	1	0	4	4	6	7	3	3	2	0	1
10 ..	4	2	6	2	5	6	4	2	7	9	5	9	3	5
9 ..	6	2	1	3	3	3	6	7	6	9	4	4	7	9
8 ..	6	4	7	8	8	11	3	8	7	4	8	7	4	4
7 ..	4	3	4	7	6	3	5	6	3	5	4	13	2	7
6 ..	1	5	5	4	6	3	2	3	4	4	4	5	5	6
5 ..	1	2	0	2	6	3	5	1	3	2	1	3	5	9
4 ..	3	0	1	1	2	1	1	1	4	1	2	4	5	3
3 ..	0	1	2	2	0	2	1	1	0	1	0	3	0	4
2 ..	0	0	0	0	1	2	0	0	1	0	0	1	0	1
1 ..	0	0	0	3	0	0	0	1	0	1	0	1	0	1
0 ..	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Below umbilicus.	1	0	0	0	0	1	1	0	1	2	2	1	1	1

The fact that a definite immunity to malaria is established in these children as the result of prolonged exposure is clearly shown in Table XII, which sets out the spleen and parasite indices for children of different ages during the malaria season and the 'non-malaria' season. To prepare this table all examinations made in September, October or November 1929 and 1930 have been combined to form the 'malaria season' table, and all the other examinations have been combined to form the table for the 'non-malaria' season. In both cases the parasite rate is highest in the youngest children, and decreases markedly with increasing age, while the spleen rate is lower in the younger children than in the older ones. Both the spleen rate and the parasite rate rose in all age groups on the advent of the malaria season, showing that the immunity developed in the older children is

relative only, and that they are still susceptible to infection. The immunity developed is sufficient to ensure that parasites appear in the peripheral blood on a few occasions only, as is shown by the fact that in the malaria season the parasite rate in the older children is disproportionately low when compared with the spleen rate.

TABLE XII.

Spleen and parasite rates, by age groups, in Indri during the non-malaria season and the malaria season.

Age.	0–1–2	3–4	5–6	7–8	9–10
I. Non-malaria season.					
Number examined ..	16	59	135	114	244
Spleen rate ..	6	46	64	63	63
Parasite rate ..	31	34	20	9	12
II. Malaria season.					
Number examined ..	9	22	61	37	92
Spleen rate ..	33	86	80	75	84
Parasite rate ..	45	54	34	27	21

Darar.

Darar lies on a small eminence between the beds of the Old and the New Western Jumna Canals, about a mile and a half from the new canal and a mile from the bed of the old canal, which is now used in the monsoon as an escape. It was visited in 1846 by Baker and Dempster, who reported a spleen rate of 60 per cent amongst children and 10 per cent amongst adults, while the level of the water in the wells was 20 feet below the ground. They do not definitely state whether the village made use of canal water at that time, but class it as being near the canal and influenced by it; it is probable that the swamps at the side of the canal extended to within a short distance of the village. The new re-aligned canal runs a mile and a half to the west of the village, and there are no seepage swamps in connection with it in this district. The land around the village is now quite dry except for three exceptionally foul cattle ponds, and a pit on the site of an abandoned brick kiln about half a mile from the village. Irrigation is entirely from wells, and the subsoil water is 20 feet below ground. As it proved to be one of the least malarious villages examined in July 1929, it was chosen for the monthly examination as a representative healthy village.

Anopheline mosquitoes are at all times few in the houses and cattle sheds in the village, *A. culicifacies* particularly so; on only one occasion was more than one found, and then they were believed to have bred in grassy pools around the village

which had dried up at the time of our visit. On no occasion has a breeding-place of this species been found near the village, and it is believed that the few that have been found have flown from distant breeding-places. The numbers of the different species of anophelines caught in this village are given in Table XIII.

TABLE XIII.

Numbers of the different species of adult anophelines caught in Darar.

Date.	*A. subpictus.*		*A. culicifacies.*		*A. fuliginosus.*		*A. stephensi.*	
	F.	M.	F.	M.	F.	M.	F.	M.
23-5-29 ..	5	0	1	0	0	0	0	0
6-7-29 ..	6	1	0	0	0	0	0	0
10-8-29 ..	11	4	0	0	8	0	0	0
28-11-29 ..	11	0	0	0	0	0	0	0
18-12-29 ..	7	0	0	0	0	0	0	0
22-1-30 ..	0	0	0	0	0	0	0	0
19-3-30 ..	0	0	0	0	0	0	0	0
28-4-30 ..	0	0	0	0	0	0	0	0
6-8-30 ..	84	11	11	2	10	0	5	0
6-9-30 ..	7	1	0	0	1	0	0	0
22-10-30 ..	24	1	1	0	3	0	0	0

The findings in the blood and spleen examinations, set out in Table XIV, show that there was an almost complete absence of malaria throughout the whole period, except for a very few cases in the autumn of 1930. At no time was there any complaint of malaria by the villagers. Except for minor variations, possibly due to the error of small samples, the spleen rate remained more or less constant at about 15 per cent after the initial examination. The decrease in the spleen rate between May and August 1930 was a phenomenon seen in all villages, and was presumably due to the recovery of those cases which had been slightly infected during the previous year.

In years of subnormal rainfall it seems that that there is very little anopheline activity in this village, insufficient to keep up any active malaria. In years of excessive rainfall a sufficient number of grassy pools will be formed near the village to afford breeding-grounds for *A. culicifacies*, when, as a result of the lack of immunity in the population, it is possible that a severe epidemic might result.

TABLE XIV.

Result of blood and spleen examinations in Darar since commencement in May 1929 to October 1930.

Date.	Spleens.				Bloods.						
	No. exd.	No. positive.	Rate per cent.	A. U. cm.	No. exd.	M. T.	B. T.	Q.	Mixed.	TOTAL.	Rate per cent.
23-5-29 ..	60	18	30	8·5	25	1	1	0	0	2	8
6-7-29 ..	57	11	19	10·2	57	0	0	0	0	0	..
10-8-29 ..	49	5	10	10·0	49	1	0	0	0	1	2
16-9-29 ..	47	8	17	9 0	47	2	0	0	0	2	4
28-11-29 ..	54	9	16	7·3	54	1	2	0	0	3	6
18-12-29 ..	61	10	16	11·4	61	3	0	0	0	3	5
22-1-30 ..	59	8	14	11·2	59	1	0	0	0	1	2
21-2-30 ..	58	7	12	11·4	58	0	0	0	0	0	..
19-3-30 ..	76	10	13	10·4	76	0	0	0	0	0	..
28-4-30 ..	57	10	18	11·3	57	0	0	0	0	0	..
6-8-30 ..	113	9	8	10 0	113	0	3	0	0	3	3
6-9-30 ..	80	8	10	9·6	80	0	0	0	0	6	7·5
22-10-30 ..	67	9	13	8·1	67	4	1	1	0	6	9
TOTAL ..	838	122	15	..	803	13	13	1	0	27	3

The numerical values of the parasite counts of positive blood films in this village are set out in Table XV. The four heavy benign tertian infections all occurred in August and September 1930, thus suggesting that there was a little transmission of malaria going on at that time, and bearing out the belief that benign tertian malaria predominates at the commencement of the epidemic. One of the heavy infections with *P. falciparum* occurred in October 1930 and the other in December 1929.

TABLE XV.

Numerical values of the parasite counts seen in Darar.

Species.	Number with a parasite count, per c.mm. of					TOTAL.
	Over 5,000	1,001–5,000	501–1,000	101–500	Under 100	
*P. falciparum**	0	2	0	1	10	13
P. vivax	2	2	1	3	5	13
P. malariae	0	0	0	1	0	1

* These figures include two cases in which crescents were seen.

Tables showing the frequencies of different sizes of spleens at each examination are necessarily unreliable on account of the small numbers of enlarged spleens seen at each examination. The figures are, however, set out in Table XVI and would appear to show that, at the first examination, when the spleen rate was at its highest

(30 per cent) both moderately large (8 cm. A. U.) and small (10 cm. A. U.) spleens were present. By the beginning of September, however, small spleens were in the majority, after which the larger ones became more numerous. After the end of the malaria season the spleens gradually decreased in size until September 1930, to be followed by a considerable increase in the average size in October.

TABLE XVI.

Spleen frequencies in Darar.

A. U. Measurement.	Number with this sized spleen.												
	23-5-29.	6-7-29.	10-8-29.	16-9-29.	28-11-29.	18-12-29.	22-1-30.	21-2-30.	19-3-30.	28-4-30.	6-8-30.	6-9-30.	22-10-30.
cm.													
15 ..	0	0	0	1	0	0	0	0	0	1	0	0	0
14 ..	0	0	0	0	0	1	0	1	0	0	0	0	0
13 ..	0	0	0	0	0	2	2	0	1	2	0	0	0
12 ..	1	1	1	0	0	2	1	1	1	2	2	2	1
11 ..	3	5	1	0	0	2	2	4	1	1	3	2	0
10 ..	4	2	1	3	1	2	3	1	3	1	1	2	1
9 ..	0	1	1	2	2	0	0	0	1	1	1	0	2
8 ..	5	2	1	0	1	1	0	0	0	0	0	1	0
7 ..	2	0	0	0	3	0	0	0	1	1	2	0	1
6 ..	0	0	0	1	0	0	0	0	0	0	0	0	1
5 ..	0	0	0	0	1	0	0	0	0	0	0	0	1
4 ..	0	0	0	1	1	0	0	0	0	0	0	0	1
3 ..	0	0	0	0	0	0	0	0	0	0	0	1	0

Kambohpura.

This village was chosen as a representative sample of the normal village in the district to examine month by month; it turned out, however, that the malaria was worse in this village than in the majority of other villages, but not sufficiently so to make conclusions drawn from it unreliable. The village is built on the usual mound, formed from the ruins of old houses, at the edge of a low-lying stretch of land which was once occupied by a large shallow tank, but which was drained in 1926. The only standing water near the village now are the usual foul cattle ponds and, some six to seven hundred yards away, there are occasional collections of water in what was the deepest part of the old tank; these latter are very small, but serve

as breeding-grounds for *A. culicifacies*. Irrigation in the district is entirely from wells, the water in which is 20 feet below the ground level; there is no canal irrigation within one and a quarter miles.

The adult anophelines collected in the houses and cattle sheds within the village were mainly *A. subpictus* and *A. fuliginosus*; *A. culicifacies*, *A. stephensi*, *A. pallidus*, *A. pulcherrimus* and *A. listonii* being found in small numbers only. The only breeding-place of *A. culicifacies* found was the collections of water in the centre of the old tank mentioned before. The numbers of adults of each species caught in the houses is set out in Table XVII.

TABLE XVII.

Numbers and species of adult anophelines recovered from Kambohpura.

Date.	*A. subpictus.*		*A. culicifacies.*		*A. fuliginosus.*		*A. stephensi.*		*A. pallidus.*		*A. listonii.*		*A. pulcherrimus.*	
	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.
18-5-29 ..	1	0	0	0	2	0	0	0	0	0	0	0	0	0
26-6-29 ..	3	0	0	0	0	0	0	0	0	0	0	0	0	0
15-8-29 ..	8	1	2	0	8	0	0	0	1	0	0	0	0	0
18-9-29 ..	9	1	3	0	2	0	0	0	2	0	0	0	1	0
30-11-29 ..	9	0	0	0	0	0	0	0	0	0	0	0	0	0
20-12-29 ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-1-30 ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-2-30 ..	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-3-30 ..	0	0	0	0	3	0	0	0	0	0	1	0	0	0
2-5-30 ..	0	0	0	0	1	0	2	0	0	0	0	0	0	0
7-8-30 ..	99	12	9	2	107	3	6	0	2	0	0	0	8	0
23-10-30 ..	34	18	0	0	17	1	0	0	0	0	0	0	0	0

Work in this village was to a considerable extent hampered by the antipathy of the villagers, with the result that the numbers of children examined on some occasions is rather small. The results of the examination of these children are set out in Table XVIII, from which it will be seen that the spleen rate, high in May 1929, rapidly declines before the commencement of the malaria season, as it did in all the other villages examined at this time. There was a slight increase of the spleen rate, with an increase in the parasite rate, in September 1929, both of which gradually

declined again until the autumn of 1930, when they both increased considerably, there being a small epidemic in the village occasioning a little dislocation of work. It has already been explained that this epidemic is attributed to post-epidemic hyperendemicity, and not to the present insalubrity of the site. Very small numbers of carrier mosquitoes were to be found at any time in the village, but the unusual number of gametocyte carriers in the village afford these few an exceptional chance of becoming infected. In 1930 anophelines were slightly more numerous than in 1929, with a consequently increased severity of malaria.

TABLE XVIII.

Result of spleen and blood findings in Kambohpura since the commencement in May 1929 to October 1930.

Date.	SPLEENS.				BLOODS.						
	No. exd.	No positive	Rate per cent	A U. cm	No. exd.	M T.	B. T.	Q.	Mixed	TOTAL.	Rate per cent.
18-5-29 ..	51	21	42	10·4	51	1	3	0	0	4	8
29-6-29 ..	53	18	34	9·5	53	1	0	0	0	1	2
15-8-29 ..	48	9	19	10·3	48	6	0	0	0	6	12
18-9-29 ..	49	12	25	10·0	49	8	0	1	0	9	18
30-11-29 ..	54	12	22	7·7	54	7	0	1	0	8	15
20-12-29 ..	61	13	21	10·5	61	1	3	0	0	4	6
24-1-30 ..	49	10	20	9·4	49	2	1	0	0	3	6
24-2-30 ..	52	11	21	10·5	52	4	0	1	0	5	10
21-3-30 ..	39	6	15	9·5	39	1	0	0	0	1	3
2-5-30 ..	32	8	25	10·6	32	3	0	0	0	3	9
7-8-30 ..	52	13	25	9·8	52	0	4	0	0	4	8
8-9-30 ..	58	32	55	7·4	58	4	6	1	0	11	19
23-10-30 ..	38	23	60	9·7	38	8	4	0	1	13	37
TOTAL ..	636	188	30	..	636	46	21	4	1	72	11

The variations in the modal size of the spleen varied in accordance with the spleen rate, as in Indri, but the changes were not very marked in this village.

The numerical values of the parasite counts seen are set out in Table XX ; of the eleven cases in which high parasite counts of over 1,000 per c.mm. were seen, [illegible] occurred during September and October 1930.

TABLE XIX.

Frequencies of the different sizes of spleen in Kambohpura.

A. U. Measurement.	18-5-29.	29-6-29.	15-8-29.	18-9-29.	30-11-29.	20-12-29.	24-1-30.	24-2-30.	21-3-30.	2-5-30.	7-8-30.	8-9-30.	23-10-30.
cm.													
15 ..	0	0	2	2	0	0	0	0	0	0	0	0	0
14 ..	4	1	0	0	0	0	0	0	0	0	0	0	2
13 ..	0	0	0	0	0	0	0	0	0	2	0	0	0
12 ..	4	2	0	0	0	3	2	3	0	1	1	3	4
11 ..	2	2	0	3	1	7	1	2	2	0	6	1	4
10 ..	4	1	3	0	0	1	1	4	2	3	2	3	3
9 ..	3	5	2	0	2	0	4	1	1	1	2	5	3
8 ..	2	3	1	2	4	1	0	1	0	1	0	7	1
7 ..	2	1	1	3	2	0	1	0	0	0	0	4	1
6 ..	1	0	0	1	2	1	1	0	1	0	1	3	2
5 ..	0	2	0	1	1	0	0	0	0	0	1	3	1
4 ..	0	0	0	0	0	0	0	0	0	0	0	0	2
3 ..	0	0	0	0	0	0	0	0	0	0	0	1	0
2 ..	0	0	0	0	0	0	0	0	0	0	0	0	0
1 ..	0	0	0	0	0	0	0	0	0	0	0	1	0
Below umbilicus	0	0	0	0	0	0	0	0	0	0	0	1	0

TABLE XX.

Numerical values of the parasite counts seen in Kambohpura.

Species.	NUMBER WITH A PARASITE COUNT, PER C.MM. OF					TOTAL.
	Over 5,000	1,001–5,000	501–1,000	101–500	100 or under.	
*P. falciparum**	4	1	0	11	30	46
P. vivax	0	2	4	5	10	21
P. malariae	1	2	0	1	0	4
Mixed *P. vivax* and *P. falciparum*.†	1	0	0	0	0	1

* These figures include 9 cases with crescents.

† This case had 120 crescents per c.mm.

Records of individual children.

In the three villages which were examined monthly a record was kept of the name, father's name, age, sex and community of all children examined, and an endeavour made to keep individual histories for each child. This proved difficult, as young children did not always give exactly the same name or father's name on successive occasions, and consequently were entered in the books under two or more different names. This accounts for the large number of children entered as having been seen once only, but it is believed that in the records of children seen more than once, which are the only ones here dealt with, a fair degree of accuracy has been maintained, and confusion between children has not arisen.

The deductions that may be made from the histories of these children are :—

(1) In no case did it prove that the whole population was infected with malaria in the course of the year, though in Indri the great majority were so infected. Table XXI shows the number of children examined in each of the three villages, (*a*) more than once, and (*b*) more than five times, and the percentage of these showing a positive blood, an enlarged spleen, or either of these signs, at one examination or another.

TABLE XXI.

Percentage of children examined showing positive blood, enlarged spleen, or either of these at any examination.

Village.	Number examined.	Percentage showing		
		Positive blood.	Enlarged spleen	Either of these signs.
(a) Children examined more than once.				
Indri	140	57	83	90
Kambohpura ..	119	35	45	66
Darar	143	13	22	30
(b) Children examined more than five times.				
Indri	61	60	91	95
Kambohpura ..	39	53	49	72
Darar	41	22	32	41

(2) The composition of the spleen rate is variable ; it is not the case that some children have permanently enlarged spleens, while in others it is permanently impalpable, but that a continual change is taking place in the population with enlarged spleens. This is illustrated in Table XXII.

TABLE XXII.

Number of children showing enlargement of the spleen at any examination, and percentage of these showing change in their spleen condition from palpable to impalpable or vice versa.

Village.	Number.	PERCENTAGE SHOWING	
		One change in their spleen condition.	More than one change in spleen condition.
(a) Children examined more than once.			
Indri ..	116	23	13
Kambohpura	54	61	22
Darar ..	32	37	44
(b) Children examined more than five times.			
Indri	55	26	23
Kambohpura ..	19	53	37
Darar	13	7	64

In the two less malarious villages a greater number of those showing enlarged spleens at some time show a change in their spleen condition than in Indri; this may be ascribed to the fact that infections in these villages being few, the possibility of double infections, with possibly more than one strain of parasite, is less than in Indri, and consequently the severity of the disease is lessened, with shorter duration of enlargement of the spleen.

(3) The spleen, once enlarged, does not remain constant in size, but shows marked variations. The average difference between the maximum and the minimum apex-umbilicus measurements in children with enlarged spleens, seen more than once, in Indri, Kambohpura and Darar was respectively 4·4 cm., 2·9 cm., and 4·0 cm.

(4) A spleen, when it first becomes palpable, usually rapidly enlarges to within 10 cm. of the umbilicus, that is, projecting at least three centimetres below the costal margin. Spleens which, when first seen, are of smaller size than this are generally transitory only. In Indri on 58 occasions children who, on their previous examintion, had had impalpable spleens, were found to have a palpable spleen on subsequent examination; in 40 of these the spleen when first seen was within 10 cm. of the umbilicus, and in 77 per cent of this group the spleen remained enlarged on every subsequent occasion that the child was examined. In 18 the spleen, when first seen, was more than 10 cm. from the umbilicus, and in only 28 per cent of this group did the spleen remain palpable thereafter.

In Kambohpura such figures would be misleading, because the majority of such spleens were seen at the last two examinations, when the spleen rate rose considerably, and there was consequently no criterion as to whether the enlargement was transient or not. The figures for Darar are too small to be significant.

(5) The appearance of parasites in the peripheral blood of a person, previously known to have had a negative blood but an enlarged spleen, is usually associated with an increase in the size of the spleen. Of 68 such cases seen in Indri, the spleen became further enlarged on the appearance of a positive blood in 68 per cent, in 22 per cent the size remained unchanged, while in 10 per cent only had the previously recorded size of the spleen decreased.

(6) Infection of the peripheral blood is normally, though not invariably, associated with enlargement of the spleen, the parasite rate being higher in those with enlarged spleens than in those without; there was, however, no particular size of spleen with which a positive blood, or a high parasite count was more usually associated.

TABLE XXIII.

Parasite rate in those with and in those without enlarged spleens.

Village	Parasite rate	
	In those with enlarged spleens, per cent.	In those without enlarged spleens, per cent
Indri	26	9
Kambohpura ..	20	8
Darar	7	3

(7) Infection of the peripheral blood is normally of short duration. Of the 80 children examined more than once in Indri showing infection of the peripheral blood, 62 per cent showed infection on one occasion only; in only 28 per cent were positive blood films seen on two or more successive occasions, the remaining 10 per cent having positive blood on two or more occasions separated by intervals in which the film was negative.

(8) Very large spleens, projecting to within 2 cm. of the umbilicus or less, are only infrequently associated with a positive blood film, and probably represent some recent rapid acquisition of immunity, subsequent to one or more severe attacks of malaria. Such spleens were seen in Indri on 29 occasions, in only 2 or 7 per cent of which was a positive blood film seen at the time; in one of these the infection was a heavy one, with 11,300 *P. falciparum* per c.mm. The association of these very large spleens with severe malaria is shown by the fact that they occur most commonly in the most malarious villages, and their connection with immunity by the fact that they are rarely seen in association with a positive blood film, a fact which has been repeatedly observed before.

EXAMINATION OF OTHER VILLAGES.

During the original survey in May and June 1929 a number of other villages besides those already described were visited. During the malaria seasons of 1929 and 1930 attempts were made to revisit as many of these as possible, the majority being visited five times; a few were never revisited as they did not offer sufficient material for study. In this way forty-six visits were made to fourteen villages, and 2,230 children examined for enlarged spleen, 622 or 28 per cent being positive; thick blood films were taken by the counting method of Sinton (1924) from 2,149 children, of whom 269 or 12 per cent showed parasites in their peripheral blood.

The different species of parasites were found in the following numbers:—

P. falciparum	133 or 49	per cent.
P. vivax	125 or 47	,,
P. malariae	10 or 4	,,
Mixed *P. falciparum* and *P. vivax* ..	1 or 0·4	,,

Mixed infections were few in this series, partly because, where the parasite rate is very low, as here, they are rare, and partly because in the vast majority of the infections seen the parasites were very scanty, and they have been missed. As has been recently pointed out by Knowles and Senior White (1930), it is difficult to diagnose the species on the appearance of a few parasites only, and it is far more difficult to diagnose the presence of two species on the appearance of two or three parasites only.

The details of the surroundings of each of these villages, with the chief breeding-places and the presumed cause of the malaria in them have been already dealt with. The full details of the examinations of the children in them are set out in Table F, in the Appendix, showing the spleen rate, average size of the spleen and parasite rate, with the number of each species of parasite found, and the frequencies of the different classes of spleens at each examination (Table G). From these it will be seen that similar changes were taking place in all of them, though differing in degree. From the commencement of the examinations in May 1929 there was a great decrease in the spleen rate of all villages until the monsoon period, similar to that which took place in Indri, Darar and Kambohpura. A few villages only were examined during August and September 1929 owing to the pressure of other work, but from those that were seen, as well as from Kambohpura and Darar, it was decided that there was a minimal amount of malaria present. When the examinations were recommenced in August 1930 the spleen rate had further decreased, but started to increase again in September and October, when there was a definite epidemic in Taraori, and a slight epidemic in Ghogripur, Munak, Shahpur and Singhoa. The parasite rate was low in all villages throughout until August 1930, when there was a very marked increase in Taraori and a slight increase in all the other villages except Rhamba.

The relative prevalence of the different species of parasites showed variations in the different months. The most reliable figures for the dry weather are those from Indri, Darar and Kambohpura, which have already been given. In these villages now under consideration the benign tertian infections were seen earlier in the monsoon than the malignant tertian, which did not become common until September, the figures for the malaria months being :—

Number examined :	August. 348	September. 544	October. 407
Parasite rate per cent ..	9·2	15·4	21·5
P. falciparum rate per cent ..	2·8	6·4	10·0
P. vivax rate per cent ..	6·4	8·3	10·5
P. malariae rate per cent ..	0	0·7	0·75
Mixed infection rate per cent ..	0	0	0·25

Table J, in the Appendix, showing the results of the parasite counts, illustrates the absence of malaria in 1929 by the fact that in these villages only one heavy parasite infestation was seen in the period, an infection with 3.900 *P. vivax* per c.mm. In 1930, it will be seen, the majority of the heavy infections with *P. vivax* occurred in the early part of the malaria season, August and September, those that were encountered in October being for the most part only slight, and presumably recovering, infections. The infections with *P. falciparum* showed no such variations from month to month, the relative proportions of heavy and slight infections remaining practically the same during the three months of August, September, and October.

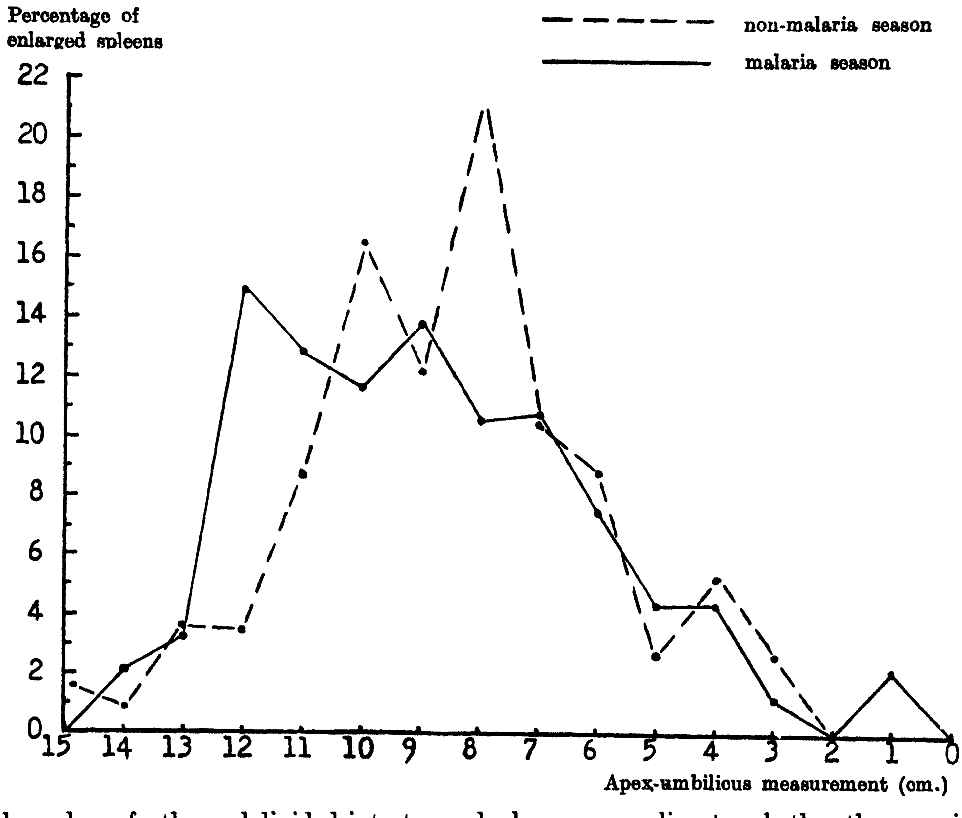
The relation between the size of the spleen and the severity of the malaria in a village.

As the number of enlarged spleens seen in some of the less malarious villages was very small, and frequency curves are therefore difficult to construct for each village, they have been grouped together in accordance with the spleen rate in constructing spleen frequency tables. In order to make this record complete the examinations for Indri, Kambohpura and Darar have been included in their proper places, and the spleen frequency tables constructed are given in full in Table G in Appendix. In general the large spleens, that is, those with a small apex-umbilicus measurement, are seen only in villages which at the time have high spleen rates, and the proportion of the large spleens to the total number of spleens measured

varies roughly with the spleen rate. There are, however, more conditions than one leading to a high spleen rate in a village; thus Indri, which is the most malarious village dealt with, has a spleen rate of 50 per cent only when the malaria is at a minimum, at the end of the hot weather, while Taraori, normally only slightly malarious, has a spleen rate of 50 per cent when an epidemic is at its height. It was thought that there might be a difference in the spleen frequency curves of two such villages and therefore the groups into which the villages have been divided

Graph I.

Spleen frequencies in villages with spleen rates between 51 *and* 60 *per cent.*
(a) *During the malaria season.* (b) *During the non-malaria season.*



have been further subdivided into two sub-classes, according to whether the examination was made during the malaria season (September to November) or during the non-malaria season. Such subdivision is not practicable in the case of villages with spleen rates under 20 per cent or over 60 per cent. The full details showing the results of such subdivision are set out in Tables H and I in the Appendix, and here illustrated by spleen frequency curves for villages with spleen rates between 50 and 60 per cent in the malaria season and in the non-malaria season. From

these it will be seen that in the former the modal size of spleen is much smaller than in the latter; that is, the modal size of spleen seen during an epidemic is smaller than that seen in a village with a high spleen rate due to past very severe malaria. This is well shown in the curve, and is the case in all groups except that for villages with spleen rates between 40 and 50 per cent, in which the mode is the same for both classes of village. It is thought that this is because the results in the villages examined during the non-malaria season were unreliable, as they include two villages examined during May 1929, which then had an unusually high spleen rate, which may have been due to a Spring epidemic, which was just subsiding.

The age distribution of infections.

The tables showing the age distribution of enlargement of the spleen, and of positive bloods, show similar changes to those already remarked on in Indri. During the period when there was no active malaria, which includes all the examinations made during 1929, and those made in August 1930, the spleen rate varies directly with the age of the children, being greater in the older children than in the young ones; the increase is gradual and progressive. The parasite rate, however, is slightly higher in the very young children under three years of age than in those above this age, in whom it remains constant.

TABLE XXIV.

Age distribution of enlargement of the spleen and infection of the peripheral blood in villages other than Indri, Darar, Kambohpura, and Kunjpura.

(1) *Non-malaria season.*

Age group ..	0–1–2	3–4	5–6	7–8	9–10
Number examined ..	63	219	330	323	276
Spleen rate ..	10	17	20	27	33
Parasite rate ..	15	8	8	8	8

(2) *Malaria season.*

Age group ..	0–1–2	3–4	5–6	7–8	9–10
Number examined ..	62	193	258	217	220
Spleen rate ..	26	30	33	32	34
Parasite rate ..	31	31	18	18	14

N.B.—These tables include only those children in whom both blood and spleen were examined, and for whom reliable particulars of age are available.

During the malaria season, however, the spleen rate in the young children rises, equalling that in the older children. There is a definite decrease in the parasite rate with increasing age, which would indicate that there is even in these villages, some immunity developed in the older children. This is borne out by the table showing details of the values of the parasite counts encountered at different ages, from which it will be seen that the highest parasite counts are most frequently met with in children under five years of age.

Thus of 63 infections, both benign and malignant tertian, seen in children under five years of age during the malaria season of 1930, 24 or 38 per cent were greater than 1,000 per c.mm., while of 57 similar infections in children aged seven to ten, in the same period, only 15 or 26 per cent were greater than 1,000 per c.mm.

TABLE XXV.

Age distribution of parasite counts seen in children, in other villages than Indri, Darar, Kambohpura, and Kunjpura.

(1) *Non-malaria Season.*

Age.	*P. falciparum.*					*P. vivax.*				
	Over 5,000	1,001–5,000	501–1,000	101–500	1–100	Over 5,000	1,001–5,000	501–1,000	101–500	1–100
0–1–2 ..	0	0	0	0	2	0	0	0	1	0
3–4 ..	1	0	0	1	4	1	1	0	0	1
5–6 ..	1	1	0	3	12	1	1	0	1	2
7–8 ..	1	1	2	2	8	0	4	0	2	4
9–10 ..	0	0	0	2	9	1	0	1	3	2
(2) *Malaria season.*										
0–1–2 ..	2	2	0	0	2	4	1	1	4	1
3–4 ..	6	1	2	2	5	2	6	8	9	5
5–6 ..	3	3	0	5	5	4	2	4	9	7
7–8 ..	1	4	4	2	8	2	1	0	2	2

N.B.—Any infections in which the parasites were not counted have been omitted from these tables.

Discussion.

It was unfortunate that owing to climatic conditions this research was undertaken at a time when the malaria was far below its normal level, and that no example of fulminant malaria was seen, but nevertheless some conclusions as to the malaria history of the district may be drawn.

The increased seasonal prevalence of malaria is first seen at the end of August or the beginning of September, some six weeks to two months after the break of the monsoon, and is first marked by an increase in the number of benign tertian infections, which are at first mostly severe, with high parasite counts. The number of benign tertian infections remains more or less constant for the next two months, but the average numerical parasite infestation rapidly decreases, probably owing to the natural processes of cure. The malignant tertian infections reach their height at a later date than the benign tertian, and remain common for the next three months, until December, there being no marked reduction in the average numerical values of the parasite infestations. Shortly after the initial appearance of fresh benign tertian infections there is a marked and rapid increase in the spleen rate in the affected villages, with an associated increase in the modal size of spleen. The diminution in the spleen rate after its height has been reached is at first rapid, there being a marked decline between October and January, from which date it slowly decreases, to reach its minimum at the beginning of August. There was no evidence of any Spring epidemic in any of the villages examined, and consequently its effect on the parasite rate and spleen rate cannot be gauged. During 1930 the active transmission of malaria apparently first started at the beginning of August, judging by the date of the first recorded fresh infections, and ceased about the beginning of September. This is shown by the slight decrease in the parasite rate in most of the villages examined after the middle of September, and the findings of Dr. Chowdhury in dissecting anophelines in Indri, in the middle of September, when only oöcysts were found in the carrier species of mosquito, which was attributed to the prevailing dryness of the atmosphere and consequent decreased length of life of the anophelines.

As a result of their annual infection with malaria the children develop a distinct immunity, which is relative but not absolute, as is shown by the fact that there is a marked increase in the spleen rate in the older children during the malaria season, showing that they are susceptible to infection, but the increase in the parasite rate is small. They receive and succumb to fresh infections, but are sufficiently immune to ensure that only on a few occasions do parasites appear in numbers in the peripheral blood. The young children show more marked variations in their spleen rates than in their parasite rates, and it would seem that when these non-immune children are infected in the autumn they repeatedly show parasites in their peripheral blood, with high parasite counts and enlargement of the spleen. In the ensuing year the spleen diminishes in size and becomes impalpable, although the continued presence of a chronic infection is shown by the repeated appearance of small numbers of parasites in the peripheral blood. Thus the presence of a chronically enlarged

spleen seems to be one of the first signs of the presence of an acquired immunity to malaria, the older children showing a smaller decrease in the spleen rate, and a greater decrease in the parasite rate than the younger ones. In Indri this period of early relative immunity to malaria commences at about five to six years of age, after which the spleen rate remains constant in the non-malaria season; in the other less malarious villages there appears to be no marked line of demarcation between the two periods.

It is highly probable that the children who have not yet developed any signs of immunity would show the highest mortality during an epidemic, and that this mortality would be greatest amongst the youngest children who have had the least chance of developing any immunity, that is, amongst children under one year of age. Christophers (1911), however, has demonstrated that the greatest relative increase of mortality during an epidemic is amongst children aged one to four years. It is not clear, however, why the relative increase over the normal should be taken as the criterion of the mortality inflicted, instead of the actual increase over the normal. In studying the figures for Amritsar District, an area which is well known on account of Christophers' study, and calculating the death rates per mille per annum for the various age group of the population since 1890, it is seen that in years when epidemic malaria prevailed the actual increase in the mortality was in all cases greatest amongst the youngest children aged under one year. but that on account of the normally very high death rate in this group the relative increase is less than in the age group of one to four years. It is, therefore, these young children who have not yet had a chance of acquiring immunity, who are most susceptible to malaria, and amongst whom the greatest mortality is seen during an epidemic, the mortality being greatest amongst those who have been exposed to the influence of malaria for the shortest time.

TABLE XXVI.

Variations from the normal in the death rates per mille in various age groups in Amritsar District, during years of epidemic malaria prevalence.

Age group	Under 1	1–4	5–9	Over 9.
Year.				
1890	+57	+6	+4	−2
1892	+94	+34	+5	+1
1894	+87	+43	+2	−1
1900	+41	+25	+0	−9
1908	+131	+122	+18	+3

The mechanism of the production of epidemics of malaria in the Punjab was first outlined by Christophers (1911), who showed that the determining causes were excessive rainfall and scarcity of food, the former being an essential while the latter was an almost equally powerful influencing factor. The localization of epidemics did not necessarily coincide with the heaviest rainfall, but depended to a great extent on the amount of flooding experienced.

The subject has since been investigated by Gill (1928), who believes that the requirements for the production of an epidemic are an upset in the equilibrium between the immunity of the population and the dose of parasites received. The ideal conditions are a decrease in the immunity as the result of a sequence of only slightly malarious years, augmented possibly by the debilitating effect of famine on the people, and an increase in the dose of parasites received as a result of a heavy monsoon with a prolonged period of high humidity and consequent lengthened average life of the anophelines.

While we agree in principle with this theory, the fact that we are able to demonstrate marked signs of immunity in the older children in Karnal, even after four successive years of deficient rainfall, makes us believe that the effect of a series of years of low rainfall is not so much to lessen the immunity of the general population, as to allow of the growth of an infant population, the larger part of which has never been infected with malaria and is consequently non-immune, the immunity in the older children and the adults being but little affected. In a year of excessive rainfall and high humidity these children will be infected early, and will show severe symptoms, and numerous gametocytes in the peripheral blood. The presence of this relatively large population heavily infected, with numerous gametocytes, should be sufficient to produce, towards the end of the epidemic, a very high sporozoite rate amongst the anophelines, with consequent repeated infection of the adults with many strains of parasites.

The fact that the epidemics always occur at the end of the period during which the transmission of malaria is possible, and not at the beginning as is the rule in more highly endemic areas, is explained by the preliminary necessity of creating a population of gametocyte carriers. One of the outstanding facts which has struck us is the paucity of crescent carriers seen in the population before and at the beginning of the malaria season. Reference to Table J, in the Appendix. will show that only two cases with crescents were seen in villages other than Indri, Darar, and Kambohpura, during 1929, though 780 children were examined, 52 proving to be infected with *P. falciparum*. In all of these cases sufficient blood was examined to have seen crescents had they been present in sufficient numbers to be infective to anophelines. At least a month normally elapses between the date of an infective feed for an anopheline on a crescent carrier, and the date of the appearance of crescents in the blood of the person subsequently infected by that anopheline. The incubation period in the anopheline is approximately ten days, with a further ten days incubation period in man, and normally a further ten days before the appearance of gametocytes in the case of *P. falciparum*. A considerable time must therefore

elapse before a large population of gametocyte carriers can be created by a process of geometrical progression. If the period of transmission is sufficiently long, and there is a suitable non-immune infant population, this will culminate in a fulminant epidemic at the end of the malaria season.

Summary.

An intensive survey was made of certain villages in the Karnal District, Punjab, with a view to following the epidemic cycle throughout the year. This intensive examination consisted of (1) the weekly examination of a single village for the monsoon period of 1929, (2) the monthly examination of three villages from May 1929 to October 1930, and (3) repeated examinations of fourteen other villages during the monsoon periods of 1929 and 1930.

Anopheline catches were made throughout the whole period; the various types of breeding-places are described and analysed according to the species selecting them. By means of regular weekly catches in a selected place an analysis of the seasonal distribution of each species was obtained. It is concluded that *A. culicifacies* is the only important transmitter of malaria in the district.

The usual breeding-places forming sources of danger to villages are described, and illustrated by the comparison of a series of villages.

The weekly examination of a single village yielded little result on account of the almost complete failure of the monsoon in 1929.

The monthly examination of three villages, chosen to represent the most malarious, the least malarious, and the normal village of the district, is described in detail. The seasonal changes in the spleen and parasite rates are described, together with the seasonal changes in the modal size of spleen. and the numerical value of the parasite infestations. The adult and larval anopheline catches made at each visit to these villages are given in full.

A record was kept of the history of a large number of individual children in these villages throughout this period, and the following conclusions drawn:—(1) In no case did it prove that the whole population was infected with malaria in the course of the year; (2) the composition of the spleen rate is variable; (3) the spleen, once enlarged, does not remain constant in size, but shows marked variations; (4) a spleen, when it first becomes palpable, usually rapidly enlarges to within 10 cm. of the umbilicus; (5) the appearance of parasites in the peripheral blood is usually associated with further enlargement of the spleen, if this was previously enlarged; (6) infection of the peripheral blood is normally associated with enlargement of the spleen; (7) infection of the peripheral blood is normally of short duration and (8) extremely large spleens are associated with a condition of immunity following on severe malaria.

In addition to the village examinations already described, 46 visits were paid to fourteen other villages, and over 2,000 children examined. The seasonal changes

in the parasite rate, the spleen rate, and the species of parasite found are described.

The relation between the modal size of the spleen and the severity of malaria in the villages is described.

The infections are analysed according to their age distribution in the non-malaria season and in the malaria season, and it is concluded that a definite relative immunity to malaria is present in the older children, despite the recent freedom of the district from severe malaria.

The relation of these observations to epidemic malaria in the Punjab is discussed.

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APPENDIX.

Table A.

Epidemic figures, Karnal District.

Towns.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.	1928.	1929.	1930.
Karnal	1·9	1·5	Influenza epidemic.	2·8	Figures not available.	4·6	2·8	3·8	1·3	4·4	2·1	1·2	1·4	2·2	1·4
Kaithal ..	1·7	1·8		3·1		5·5	2·2	6·2	1·6	2·5	1·9	1·8	1·2	1·4	1·2
Panipat ..	1·4	1·9		1·3		4·2	1·5	2·1	2·2	7·5	1·5	0·4	1·0	1·1	1·3
Shahabad ..	1·5	1·5		1·7		7·8	2·1	2·0	1·8	2·3	1·4	1·4	0·9	1·4	1·4
Thanesar ..	2·1	1·9		2·8		2·3	3·7	2·3	1·2	1·3	1·8	1·2	3·7	1·6	2·8
Total Towns ..	**1·5**	**1·6**		**2·1**		**4·7**	**1·9**	**2·9**	**1·7**	**4·6**	**1·7**	**0·9**	**1·1**	**1·3**	**1·3**
Rural Circles, Karnal ..	1·5	2·0		3·0		3·0	2·6	5·4	2·4	3·1	2·3	1·2	0·9	1·2	1·6
Gharaunda ..	1·1	1·4		2·1		1·8	1·9	3·0	1·9	3·7	1·7	0·9	0·7	1·1	1·4
Nissang ..	1·3	1·5		2·5		3·0	2·8	5·4	1·8	2·6	2·6	1·4	0·7	1·6	1·7
Buthana ..	1·0	1·3		2·1		2·4	2·9	4·8	2·1	1·7	2·2	1·0	0·7	1·0	2·1
Indri	1·3	1·6		2·3		2·6	1·8	4·1	1·8	1·6	1·8	0·9	0·7	1·3	1·7
Rajaundh ..	1·1	1·5		1·4		2·4	2·0	6·5	1·7	2·0	3·0	1·2	0·9	1·3	1·4
Pundri	1·4	1·9		2·0		2·7	3·4	4·8	2·1	2·4	2·3	1·1	1·2	1·5	1·3
Kaithal ..	1·3	2·3		1·9		2·9	2·3	7·8	2·1	2·5	3·2	1·0	0·8	1·5	1·7
Assandh ..	0·9	1·3		1·6		1·9	1·8	4·4	1·6	1·6	1·8	2·4	0·8	1·4	1·3
Ghula	1·7	1·6		3·7		4·9	1·5	5·0	1·6	2·7	2·4	2·0	0·7	1·4	1·5
Urlana ..	1·2	1·5		2·7		1·8	2·0	4·5	1·6	5·0	2·7	0·8	0·8	1·1	1·8
Samalka ..	0·9	1·3		1·8		1·9	1·9	2·2	2·1	6·0	2·2	0·9	0·8	1·3	1·4
Panipat ..	1·0	1·1		2·5		2·3	2·0	2·7	2·7	4·6	1·8	0·8	0·6	1·3	1·8
Pehawa ..	1·5	1·5		2·6		2·8	1·7	4·6	1·9	2·9	3·1	1·6	0·7	1·7	1·7
Ladwa	1·8	3·0		3·6		4·9	2·5	2·7	1·6	1·6	1·9	1·8	1·1	1·7	4·0
Shahabad ..	1·7	1·3		2·4		2·3	2·3	3·8	1·9	1·9	2·0	1·2	0·7	1·3	1·7
Thaska	1·7	1·3		2·6		3·0	2·2	4·2	2·2	3·0	2·2	1·3	0·7	2·1	2·1
Thanesar ..	1·4	3·9		3·1		3·0	3·4	3·8	2·3	2·1	2·1	1·2	1·0	2·1	2·8
Radaur ..	1·4	1·5		2·7		4·9	2·2	3·1	2·5	1·3	1·8	1·3	1·2	2·1	5·4
Singhair ..	1·7	1·6		3·2		2·9	3·1	2·7	2·5	1·6	2·2	1·0	..	..	..
Total Rural Circles	**1·2**	**1·6**		**2·1**		**2·5**	**2·2**	**4·2**	**1·7**	**2·8**	**2·0**	**1·0**	**0·7**	**1·2**	**1·7**
Grand Total ..	**1·2**	**1·6**		**2·1**		**2·5**	**2·2**	**4·1**	**1·8**	**3·0**	**2·0**	**1·0**	**0·7**	**1·2**	**1·6**

TABLE B.

Weekly average temperature, humidity, and rainfall for the monsoon period of 1929.

Week ending	HUMIDITY.		TEMPERATURE.		Rainfall total for week.
	Mean 9 A.M.	Mean 4 P.M.	Mean Max.	Mean Min.	
1–6–29 ..	35	25	112	80	0·0
8–6–29 ..	43	25	110	81	0·0
15–6–29 ..	41	27	105	87	0·03
22–6–29 ..	50	42	103	78	0·08
29–6–29 ..	54	42	100	77	0·0
6–7–29 ..	64	45	99	77	0·57
13–7–29 ..	59	45	102	80	0·0
20–7–29 ..	69	50	95	80	1·34
27–7–29 ..	76	69	90	77	2·38
3–8–29 ..	80	76	88	77	0·94
10–8–29 ..	80	78	91	77	0·76
17–8–29 ..	81	81	92	77	0·08
24–8–29 ..	74	69	87	76	0·93
31–8–29 ..	79	60	87	76	2·03
7–9–29 ..	60	50	93	75	0·0
14–9–29 ..	54	39	96	75	0·0
21–9–29 ..	52	34	98	72	0·0
28–9–29 ..	58	36	99	71	0·0
5–10–29 ..	59	41	92	74	0·11

TABLE C.

Weekly average temperature, humidity, and rainfall for the monsoon period of 1930.

Week ending	Humidity.		Temperature.		Rainfall total for week.
	Mean 9 A.M.	Mean 4 P.M.	Mean Max.	Mean Min.	
7-6-30 ..	28	22	108	80	0·0
14-6-30 ..	43	34	102	80	2 31
21-6-30 ..	58	51	92	75	0·69
28-6-30 ..	66	44	93	78	0·70
5-7-30 ..	63	63	91	77	4·12
12-7-30 ..	75	57	90	78	0·12
19-7-30 ..	76	62	90	77	4·95
26-7-30 ..	79	61	94	79	1·39
2-8-30 ..	82	75	88	76	1·20
9-8-30 .	78	62	91	76	1 69
16-8-30 ..	69	63	90	78	0 53
23-8-30 ..	57	46	96	80	0·0
30-8-30 ..	55	47	100	79	0·0
6-9-30 ..	65	45	92	74	0·63
13-9-30 ..	64	63	98	76	0·55
20-9-30 ..	50	60	91	75	0·0
27-9-30 ..	53	31	96	67	0·0
4-10-30 ..	46	24	97	65	0·0

TABLE D.

An analysis of the monthly adult anopheline catch in terms of the percentage of the total catch for the month.

1929.		*A. culicifacies.*	*A. subpictus.*	*A. fuliginosus.*	*A. stephensi.*	*A. pallidus.*	*A. hyrcanus.*	*A. barbirostris.*	*A. maculipalpis.*	*A. listoni.*	*A. pulcherrimus.*	*A. maculatus.*
April	..	0	0	0	0	0	0	0	0	0	0	0
May	..	47	40	10	2	0	0	0	0	0	0	0
June	..	43	20	8	3	0	0	0	25	0	0	0
July	..	17	62	18	1	0 6	0	0	0·6	0	0·4	0
August	..	15	46	35	1	2	0	0	0·3	0	0	0
September	..	9	53	26	1	2	0	0	1·5	0	4	0
October	..	1	37	47	16	3	0	0	0·4	5	0·8	0
November	..	8	·38	45	0	1	0	0·4	4	3	0·2	0
December	..	14	20	18	3	0	0	0	6	39	0	0
1930.												
January	..	0	0	33	0	0	0	0	33	33	0	[illegible]
February	..	0	0	33	0	0	0	0	42	25	0	0
March	..	0·5	0	71	7	0	0	0	10	10	0·9	0·2
April	..	6	0	87	4	0	0	0	2	1	0·1	0
May	..	36	0·7	57	3	0	0	0	0	3	0	0·7
June	..	55	18	21	5	0	0	0	0	0·6	0·9	0
July	..	25	59	13	2	0	0·1	0	0·1	0	0·4	0
August	..	15	53	28	1	0·7	0	0·05	0·05	0	2	0
September	..	39	32	24	1	1	0·5	0·3	0·4	0·1	2	0
October	..	12	53	31	0·2	1	0·5	0·2	0·7	0·7	0·4	0
November	..	14	36	42	0·05	1	0·2	0·1	3	3	0·2	0
December	..	25	7	51	0·5	2	0	0·2	0	15	0	0

TABLE E.

Analysis of the monthly larval anopheline catch since the commencement of the investigation, in terms of percentage of the total number of collections made.

1929.	*A. culicifacies.*	*A. subpictus.*	*A. fuliginosus.*	*A. stephensi.*	*A. pallidus.*	*A. hyrcanus.*	*A. barbirostris.*	*A. maculipalpis.*	*A. listonii.*	*A. pulcherrimus.*	*A. maculatus.*
April	39	6	48	6	0	0	0	0	0	0	0
May	31	51	8	10	0	0	0	0	0	0	0
June	26	42	0	18	0	0	0	10	0	3	0
July	19	7	0	5	0	0	0	0	0	0	0
August ..	14	83	3	0	0	0	0	0	0	0	0
September ..	9	52	9	0	1	16	7	0	5	2	0
October ..	No collections recorded.										
November ..	0	60	40	0	0	0	0	0	0	0	0
December ..	0	60	40	0	0	0	0	0	0	0	0
1930.											
January ..	0	0	0	0	0	0	0	0	0	0	0
February ..	0	0	0	0	0	0	0	0	0	0	0
March ..	33	0	33	17	0	0	0	0	17	0	0
April	33	0	58	0	0	0	0	0	0	0	8
May	22	12	10	51	0	3	0	0	2	0	0
June	29	42	8	21	0	0	0	0	0	0	0
July	22	78	0	0	0	0	0	0	0	0	0
August ..	13	76	3	1	0	5	2	0	0	0	0
September ..	15	61	7	0	1·5	9	5	0	0	1·5	0
October ..	10	66	9	1	4	6	2	0	0	1	0
November ..	8	49	20	0	0	14	9	0	0	0	0
December ..	20	16	28	0	0	16	12	0	8	0	0

TABLE F.

Result of blood and spleen examination from May 1929 *to October* 1930.

Date.	SPLEENS.				BLOODS.						
	No. exd.	No. pos.	Rate per cent.	A. U. cm.	No. exd.	M. T.	B. T.	Q.	Mixed.	TOTAL.	Rate per cent.
					TARAORI.						
28–5–29 ..	50	15	30	10·3	50	5	0	1	0	6	12
1–8–29 ..	55	11	20	10·4	55	7	2	0	0	9	16
11–9–29 ..	26	6	23	10·2	26	2	3	0	0	5	20
12–9–30 ..	82	35	43	8·2	82	5	14	0	0	19	23
16–10–30 ..	66	37	56	9·2	66	18	19	1	0	38	57
TOTAL ..	279	104	37	..	279	37	38	2	0	77	28
					SHAMGARH.						
13–5–29 ..	35	9	26	10·0	21	0	2	0	0	2	10
28–8–30 ..	65	7	11	10·6	65	1	3	0	0	4	6
22–9–30 ..	65	15	23	11·2	65	1	5	0	0	6	9
25–10–30 ..	47	10	21	10·7	47	4	4	0	0	8	17
TOTAL ..	212	41	20	..	198	6	14	0	0	20	10
					RAMBHA.						
21–5–29 ..	60	10	17	11·5	60	2	1	0	0	3	5
29–8–30 ..	91	13	14	8·0	91	3	3	0	0	6	7
26–9–30 ..	51	2	4	10·5	51	3	0	0	0	3	6
TOTAL ..	202	25	12	..	202	8	4	0	0	12	6
					MUNAK.						
7–6–29 ..	59	17	29	8·5	59	3	0	0	0	3	5
15–9–30 ..	83	35	42	8·9	74	4	5	0	0	9	13
17–10–30 ..	74	32	43	8·8	74	9	5	2	1	17	23

TABLE F—*contd.*

Date.	Spleens.				Bloods.						
	No. exd.	No. pos.	Rate per cent.	A. U. cm.	No. exd.	M. T.	B. T.	Q.	Mixed.	Total.	Rate per cent.
Gagsina.											
8-6-29 ..	60	10	17	10·5	60	4	1	0	0	5	8
16-9-30 ..	52	12	23	9·6	52	3	1	2	0	6	11
18-10-30 ..	63	14	22	10·1	63	2	2	0	0	4	6
Total ..	175	36	21	..	175	9	4	2	0	15	9
Dadupur.											
10-6-29 ..	40	14	35	9·7	40	1	0	0	0	1	2·5
27-7-29 ..	22	6	37	9·0	22	0	0	0	0	0	..
22-8-30 ..	41	12	28	10·2	41	2	6	0	0	8	19
24-9-30 ..	32	8	25	9·0	32	3	0	0	0	3	9
24-10-30 ..	37	7	19	9·4	32	1	0	0	0	1	3
Total ..	172	47	27	..	167	7	6	0	0	13	8
Shahpu .											
10-6-29 ..	34	19	56	9·0	34	4	0	0	0	4	12
27-7-29 ..	41	13	32	10·3	38	2	0	1	0	3	8
22-8-30 ..	45	11	24	8·6	45	1	2	0	0	3	7
24-9-30 ..	45	16	36	10·0	45	7	7	0	0	14	31
24-10-30 ..	45	15	33	10·4	45	4	9	0	0	13	29
Total ..	210	74	35	..	207	18	18	1	0	37	18
Ghogripur.											
1-6-29 ..	46	18	39	8·4	40	0	0	0	0	0	..
20-7-29 ..	43	14	33	8·7	43	1	0	0	0	1	2
25-8-30 ..	54	9	17	7·8	54	2	5	0	0	7	13
20-9-30 ..	55	27	49	9·4	55	3	4	1	0	8	15
29-10-30 ..	45	11	24	10·9	45	2	1	0	0	3	7
Total ..	243	79	32	..	237	8	10	1	0	19	8

TABLE F—*concld.*

Date.	Spleens.				Bloods.						
	No. exd.	No. pos.	Rate per cent	A. U. cm.	No. exd.	M. T.	B. T.	Q.	Mixed	Total.	Rate per cent.
					Barauta.						
1–6–29 ..	40	17	42	9·1	30	2	0	0	0	2	7
18–7–29 ..	50	19	38	10·2	50	2	1	0	0	3	6
6–9–29 ..	40	6	15	10·7	40	5	0	0	0	5	12
25–8–30 ..	52	9	17	10·1	52	1	3	0	0	4	8
28–9–30 ..	40	11	27	8·8	40	2	2	1	0	5	11
19–10–30 ..	45	10	22	10·4	45	1	3	0	0	4	9
Total ..	267	72	27	..	257	13	9	1	0	23	9
					Singhoa.						
5–29 ..	12	2	17	10·0	12	0	0	0	0	0	..
10–9–30 ..	48	13	27	8·0	48	4	7	0	0	11	23
Total ..	60	15	25	..	60	4	7	0	0	11	18
					Budha Khera.						
5–29 ..	16	6	37	11·5	16	0	0	0	0	0	..
					Jhanjari.						
5–29 ..	29	11	38	10·4	29	5	3	0	0	8	28
					Kalwaheri						
5–29 ..	18	7	39	10·0	18	0	0	0	0	0	..
					Padhana.						
5–29 ..	50	9	18	12·1	19	0	0	1	0	1	5
8–8–29 ..	60	7	12	11·4	..	1	0	0	0	1	2
					Dadupur Ranghran.						
5–29 ..	21	5	24	12·0	18	1	1	0	0	2	11

TABLE G.

Table showing the frequencies of the different sizes of spleens, arranged according to the spleen rates of the villages from which they were taken.

Apex-umbilicus measurement.	Number of spleens with this A. U. measurement in villages with a spleen rate of								
	81–90	71–80	61–70	51–60	41–50	31–40	21–30	11–20	1–10
cm.									
15	0	0	1	2	0	8	7	14	0
14	1	0	2	3	5	6	2	6	0
13	0	1	8	7	8	15	16	14	0
12	2	7	11	18	13	19	43	22	4
11	2	2	24	22	19	21	43	26	3
10	7	17	28	28	42	23	44	41	3
9	12	14	31	27	21	13	16	28	2
8	12	19	33	34	24	18	31	15	2
7	14	21	22	22	22	7	16	15	0
6	10	16	16	17	16	7	15	10	0
5	11	14	14	7	7	5	10	5	0
4	4	11	8	10	5	5	5	5	0
3	6	3	4	4	6	1	1	2	1
2	1	2	4	0	2	1	1	2	0
1	4	1	1	2	1	0	1	1	0
0	1	2	0	0	0	0	0	0	0
Below umbilicus	1	2	5	4	1	2	1	0	0

TABLE H.

Spleen size frequencies, arranged according to the spleen rate of the village concerned, seen during the non-malaria season.

A. U. measurement.	NUMBER OF SPLEENS OF THIS SIZE SEEN IN VILLAGES WITH A SPLEEN RATE OF			
	51–60 per cent.	41–50 per cent.	31–40 per cent.	21–30 per cent.
cm.				
15	2	0	8	4
14	1	4	6	1
13	4	2	7	8
12	4	6	13	14
11	10	6	14	19
10	19	10	15	29
9	14	7	12	7
8	24	8	13	17
7	12	7	5	5
6	10	8	7	3
5	3	3	5	5
4	6	0	5	2
3	3	1	1	0
2	0	0	1	0
1	0	0	0	0
0	0	0	0	0
Below umbilicus ..	4	0	2	0

TABLE I.

Spleen size frequencies, arranged according to the spleen rate of the village concerned, seen during the malaria season.

A. U. measurement.	NUMBER OF SPLEENS OF THIS SIZE SEEN IN VILLAGES WITH A SPLEEN RATE OF			
	51–60 per cent.	41–50 per cent.	31–40 per cent.	21–30 per cent.
cm.				
15	0	0	0	3
14	2	1	2	1
13	3	6	8	8
12	14	7	6	29
11	12	13	7	24
10	9	32	8	15
9	13	14	1	9
8	10	16	5	14
7	10	15	2	11
6	7	8	0	12
5	4	4	0	5
4	4	5	0	3
3	1	5	0	1
2	0	2	0	1
1	2	1	0	0
0	0	0	0	0
Below umbilicus ..	1	1	0	1

TABLE J.

Showing the numerical values of parasite infestations found in villages other than Indri, Darar, Kambohpura and Kunjpura.

1929.		Number with parasite infestation between the values stated per c mm.						Number showing crescents.*
		5,001–100,000	1,001–5,000	501–1,000	101–500	1–100	Not counted.	
May ..	M. T.	0	0	0	1	4	12	2
	B. T. ..	0	0	0	0	0	12	..
	Quartan	0	0	1	0	1	0	..
June ..	M T. ..	0	0	0	1	14	0	0
	B T. ..	0	0	0	1	0	0	..
July ..	M. T. ..	0	0	0	1	4	0	0
	B T. ..	0	0	0	0	1	0	..
	Quartan	0	0	0	0	1	0	..
August ..	M. T. ..	0	0	1	0	7	0	0
	B T ..	0	0	0	1	1	0	..
September ..	M. T. ..	0	0	0	2	5	0	0
	B. T. ..	0	1	0	0	2	0	..
1930.								
August ..	M. T ..	3	1	0	6	0	0	3
	B. T. ..	3	6	2	6	5	0	..
September ..	M. T. ..	8	2	3	6	16	0	8
	B T. ..	8	8	11	13	5	0	..
	Quartan	3	0	1	0	0	0	..
October ..	M. T. ..	6	9	5	10	11	0	17
	B. T. ..	4	4	3	16	16	0	..
	Quartan	0	2	1	0	0	0	..

* These cases showing crescents have already been shown in the previous column, according to the numerical value of the infection.

Records of the Malaria Survey of India, Vol. II, No. 3, September, 1931.

SPECIES AND VARIETIES OF THE *FUNESTUS* SERIES OF ANOPHELES.

BY

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[May 20, 1931.]

AMONG named species whose systematic position is still very uncertain are a number of forms which from their close relationship to *A. funestus* Giles may be called the *funestus* series. They are all characterized by the very large anterior tergal plates of the larva, by the presence of hairs or false scales only on the greater part of the mesonotum and by the legs being devoid of definite markings, the only ornamentation of these consisting in, very often. some paleness at the ends of the femora, etc., and sometimes very narrow yellowish banding of the tarsi. The wing resembles that of a number of species in the *Myzomyia* group, but has the following characters common to the series; fringe spots at the junction of all veins (except commonly that at vein 6); the base of the costa dark (but with or without an interruption just internal to the inner dark costal spot); no interruption in the preapical dark costal spot (as in some forms of *A. marshallii*). The female palpi have three pale bands, one at the apex including the whole of the very short terminal segment, one at the junction of segments 3–4 and one more towards the base of the organ at 2–3*. The proboscis has pale yellow labella and is otherwise dark or with, in some cases, more or less extent of characteristic 'flavescence.'

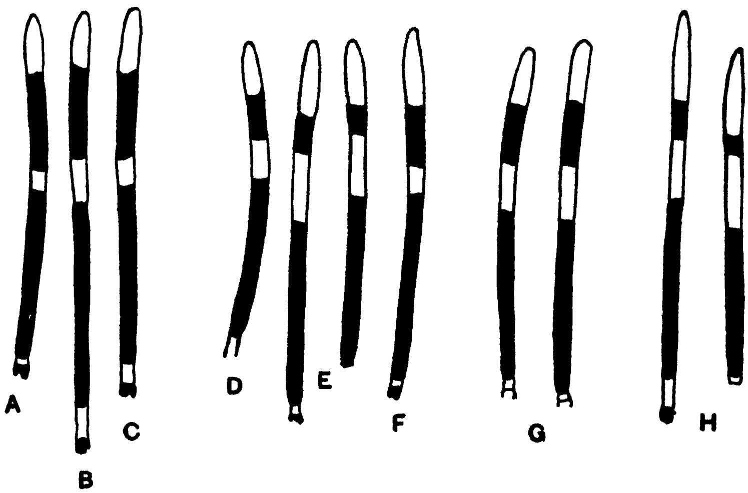
Within the series the chief variable features are in the ornamentation of the palpi, proboscis and wings. There are also small but definite distinctions in the larva which are associated with each member. The eggs where known are distinctive.

The palpi.

The modifications in the series are in the proportions of white (and to some extent in the actual proportions of the parts) forming the apical and subapical band and the dark area intervening between the two. A difference, e.g., as between

* The rudimentary basal segment being counted as segment I.

A. listonii and *A. minimus*, exists in the relative width of the second or subapical pale band. This may be (*a*) quite narrow, often $\frac{1}{4}$ or $\frac{1}{5}$ of the dark area, and in such cases the dark intervening area between the apical and subapical bands is usually about $\frac{1}{2}$, or may be even more, of the dark area between the subapical and the more basal pale band. This is the condition in practically all specimens found west of Delhi along the Himalayas and sub-Himalayan areas to the far north-west, an extent throughout which *A. listonii* is a dominant Anopheline. On the other hand (*b*) the subapical band may be a little narrower, as broad or broader* than the intervening darik band. This is the appearance seen over large tracts in the east, China, Formosa, Philippines. etc.



TEXT FIGURE 1.

Showing ornamentation of segments 3, 4 and 5 female palps in *A. listonii* and other forms.

A. A typical *A. listonii* taken at random (Kathiawar).

B. A specimen of *A. listonii* selected as showing unusually broad subapical band (Amritsar). Note, however, the proportion of the dark area.

C. A specimen from Singhbhum with an interruption on the costa, probably *A. listonii*.

D. A very usual appearance in *A. minimus* (Kowloon, China). Note the proportions of the dark area.

E. Two specimens of *A. minimus* taken at random (Burma, Assam).

F. A specimen of *A. minimus* (costal interruption and characteristic flavescence on proboscis) but with narrow subapical band.

G. Two specimens of *A. varuna* taken at random. This species may also show the appearances depicted at E.

H. Two specimens of *A. aconitus* showing usual appearances.

Drawn with camera lucida to show proportions only. The palps were unmounted and as usually seen when examining specimens.

* Very commonly, especially in *A. aconitus*, the dark band is reduced to a narrow black ring or is entirely lacking the whole terminal portion of the palps being pale.

There are, however, unfortunately intermediate appearances, especially in the eastern Indian area and it is these which require careful study. Whilst *A. listonii* from west of Delhi practically never shows any appearance that could be mistaken for any other ornamentation than that described above as (*a*), there is a tendency among specimens of what must be taken to be *A. listonii* east of this line to show some variability, not so much in the width of the subapical pale band as in the direction of a general shortening of the dark band between the apical and subapical pale band. This variation may be difficult to distinguish from a shortening of the subapical pale band in *A. minimus* and sometimes in *A. varuna* in specimens in which the subapical pale band is somewhat narrower than is usual in these species and the dark band thereby correspondingly increased. Nevertheless, as a result of identifications based on other characters it appears correct to say that if the dark band is as short or shorter than one-third of the more basal dark area, and especially if the subapical pale band is broader than is usual in *A. listonii,* the specimen is probably *minimus* and confirmatory characters should be looked for. A point has been made of this difficulty because it is undoubtedly by no means infrequent to come across specimens in the eastern Indian areas where there would be difficulty if one relied always on the presence of the two broad white bands as typically seen and it is necessary to remember that in certain areas specimens of *A. minimus* may fail to show quite such a broad band as usual, in which case the length of the dark intervening band may be a further indication. The palpal banding has, however, been made the first or primary division in the synoptic table because as a rule there is no difficulty in this matter and it is the simplest and quickest way to identify most specimens.

The palps in the male show on the outer aspect of the club about its middle and towards its upper border (*a*) an oval or triangular smallish pale area or spot, more or less characteristic of *A. listonii* and *A. funestus*, or (*b*) an extensive area of paleness giving the general effect of a mainly pale club crossed by two narrow dark bands, the actual ventral border, however, usually remaining dark, an appearance seen in *minimus, varuna* and *aconitus.*

The proboscis.

The presence, and if present the character, of flavescence on the proboscis is highly important. It is necessary to examine for this with care as if viewed in an incorrect lighting some forms of flavescence are not brought out, or light gleaming on the part may give a false appearance. Usually it is necessary to examine in various lights until the condition present is clearly and certainly ascertained. The marked flavescence seen in *A. aconitus* and many specimens of *A. varuna* is, however, more or less visible in all lights.

In *A. listonii* and many specimens of *A. minimus* flavescence is entirely absent. In *minimus*, however, a restricted, narrow flavescence commonly exists along a portion of the ventral aspect of the labium, and may be best described as a ventral tache. This is very characteristic and when present practically diagnostic. In

A. aconitus and *A. varuna* flavescence extends over the outer half or so of the proboscis, being on the whole more vigorous and sharply defined in the former species, but often almost equally distinct in the latter, in which, however, it is commonly less distinct or even, rarely, absent. In *A. varuna* also the flavescence often does not quite cover the end of the proboscis, leaving some darkness between the flavescent area and the pale labella.

*The wing.**

The markings of the wing in these forms has been much studied. It has been thought by various authors that diagnostic features could be found in (*a*) the presence or absence of a fringe spot at vein 6, (*b*) vein 6 with a pale spot in its outer half. i.e., with three dark spots as against its outer half all dark or two dark spots. (*c*) the absence of dark scales at the base of vein 3, (*d*) an interruption or not at the base of the costa internal to the inner dark costal spot. None of these characters are invariable and (*b*) and (*c*) in particular are practically valueless as critical diagnostic features though they may be helpful sometimes. The presence of a fringe spot at vein 6 in some forms is. however, so unusual that this may be taken as practically excluding these forms. The absence of a spot (in *A. aconitus*) where it is normally present is less uncommon. The presence of an interruption on the costa is so rare in some forms (*A. listonii* and *A. varuna*) that its presence is presumptive evidence against such forms. In *A. aconitus* either condition may be present, though this species is most commonly without an interruption. In *A. minimus* a spot is so usual that its presence is largely diagnostic, though its absence is not so informative in a single specimen, as it would be in a series. In this character not only is an actual pale break in the dark costa to be recognized, but the presence, even on one wing, of a pale scale or two in this situation counts as a spot.

Besides the above markings there is a certain amount of value to be attached to an extensive paling of vein 5·1, and what often accompanies this, a pale spot on 4·1 or even extensive paling of vein 2·2. These variations, however, appear to be liable to be produced under certain local conditions favouring general paling of the wing and though such paling is in general characteristic of *A. aconitus* it may appear in a high degree in other forms even to the disappearance of all dark scaling at the base of vein 3, once thought to be characteristic of *A. aconitus*. Not only may this be seen in other forms, but *A. aconitus* very frequently has vein 3 more or less dark at the base. Usually, however, the wing of *A. listonii* and *A. varuna* is noticeably dark with vein 5·1 all dark or with a small pale spot.

Larval and egg characters.

Differences in the larval and egg characters are sufficiently indicated in the systematic portion given later.

* Unless otherwise stated the female wing is always understood. The male wing so far as it has been observed appears, however, to conform in general to the female characters.

RECOGNIZABLE FORMS OF THE *A. funestus* SERIES.

The similarity of these forms and the liability to variation in the palpal marking, etc., has led Strickland (1924), whilst recognizing *A. aconitus* as distinct, to sink *A. minimus* (and with this *A. listonii*) under the African species *A. funestus.* In this he has been followed by certain other authors, notably Carter (1925), and as regards the Philippines by Manalang (1930). The question as to what systematic status should be given to the different forms is discussed later. Though it is not held that certain identification is always easy or in some particular specimens even always possible, it does appear to us that the following forms, as given below in a brief systematic résumé, are quite recognizable and have distinctive characters and distributions proper to each.

We are not in a position to speak with the same certainty regarding variations in *A. funestus* as we are regarding those in other forms as our material was limited. In respect to the Indian forms we have examined the whole collection at the Malaria Survey of India which includes very large numbers of specimens collected over the whole Indian area, and this extensive examination may really have caused us to exaggerate somewhat the difficulties and doubts in identification. Normally with the aid of the characters now given we think there should be no particular difficulty in identifying specimens of *listonii, minimus, varuna* or *aconitus.* Where the larval characters can be brought to bear also on the identification matters should be even less liable to difficulty. As regards difficulty of definition we have found this always greatly increased by examination of large masses of material, and in this respect difficulties with the present series is only what has been increasingly found with other species.

In the systematic list we give first the adult characters that can be used diagnostically, subject to occasional aberration, when collateral information must be brought to bear, and follow this in a subsequent paragraph with certain other characters which are general attributes of the species as most commonly seen, but which are too liable to variation to be of critical value.

We feel satisfied that these forms actually exist as distinguishable entities in nature and hope that the following revision may be helpful in still further establishing their characters, or should it be shown that they are in some cases the same, their final sinking as varieties or synonyms. It will be noticed that there is still much to be done, e.g., in the determination of the egg characters for all the forms and the more extended application of the larval characters noted to the elucidation of the subject.

The following species of this group appear to be definitely distinguishable.

A. funestus Giles, 1900.

(?) *A. minuta* Macquart, 1834.
A. kumasii Chalmers, 1900.
A. hebes Donitz, 1902.
var. *subumbrosus* Theobald, 1903.

Female palpi with narrow subapical band, the intervening dark band between the apical and subapical pale bands considerably longer than (twice or more) the length of the subapical pale band and approaching half the length of the dark area lying between the subapical and basal pale band. No pale fringe spot at termination of vein 6. Pale interruptions on apical half of costa much less in extent than the dark. Basal area of costa *with* or *without* a pale interruption ; if present usually of small extent. Proboscis entirely dark except labella and without any sign of flavescent area.

Vein 6 dark in outer half. Branches of veins 2 and 4 usually uninterruptedly dark except at their ends. Vein 5·1 usually continuously dark from the cross-vein to the wing margin. Vein 3 usually extensively dark in basal area ; usually with a pale spot $\frac{1}{3}$ length of vein or less.

Male palpi having the club with pale apex and a moderate sized pale area about its middle, but with no pale area at base (Evans. 1930. p. 591).

Larva.—Fronto-clypeal pattern with separate complete transverse bar anteriorly (Evans, 1930). All clypeal hairs simple, unfrayed ; inner sutural hair *simple ;* tergal plates on segments 3-7 extending backwards to include the two small oval plates ; hair 0 arising from tergal plate, simple, or bifid long and thin (Puri, 1931).

The larval characters given by Puri refer to specimens from Kenya sent as those of *A. funestus* along with a number of adults of this species by Dr. C. B. Symes. A similar condition of the tergal plates appears to hold good from the description and figure (p. 590 and fig. I, H, 4), by Evans, 1930.

Egg.—Undescribed.*

Habits.—Found especially in grassy edges of flowing water.

Distribution.—Tropical Africa throughout the continent including Sudan, but not recorded from Abyssinia, Italian or British Somaliland, Aden Hinterland, Egypt, Palestine or Mesopotamia.

A. arabica Christophers and Khazan Chand, 1915.

Female palpi as in *A. funestus.* No pale fringe spot at vein 6. Pale costal spots in outer half of costa as extensive, or nearly as extensive as the dark. Base of costa *with* a very wide pale interruption.

Larva.—A larval skin from Muscat sent by Col. C. A. Gill, I.M.S., when this species was first described in 1915 shows the clypeal hairs simple unfrayed. inner sutural hair *branched* and the small oval plates not included in the anterior tergal plate.

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* *Note.*—Since writing the above eggs of *A. funestus,* with the corresponding adults, have been sent to the Bureau by Dr. C. B. Symes (see Acknowledgments). The egg is quite unlike that of *A. listoni ;* it is not even of the 'whale-back' type, as are those of all species in the Oriental series so far seen. The following are the main characters of the egg of *A. funestus :*

Upper surface narrow, about one quarter width of egg exclusive of floats, with anterior and posterior demarcated areas, which are narrow and straight sided, with a very large re-entrant angle where the former reaches to the level of the floats. Lower surface with large conspicuous outstanding scattered granules. Floats touching margin of upper surface, with about 15-16 float ridges, which are rather smooth. Frill narrow, not continued past floats.

Egg.—Undescribed.

Habits.—Found only in slowly flowing water connected with underground aqueduct (Gill, 1916).

Distribution.—S. E. Arabia (Muscat).

This species differs from *A. listonii* in the broad interruption in the basal area of the costa and from *A. funestus* in the branched sutural hair, etc.

A. listonii Liston, 1901.*

A. fluviatilis James, 1902.

A. leptomeres Theobald, 1903.

Female palpi with narrow subapical band, the intervening dark band between the apical and subapical pale bands twice or more (often 3 or 4 times) the length of the subapical pale band and at least as a rule $\frac{1}{2}$, and never less than $\frac{1}{3}$, of the length of the dark area between the subapical and basal pale band. No fringe spot at termination of vein 6. Pale areas on apical half of costa much less in extent than dark. Base of costa *without* pale interruption or any indication of such.† Proboscis entirely dark except labella, without any sign of flavescent area.

Vein 6 dark in distal half. Branches of veins 2 and 4 and 5·1 external to cross-vein continuously dark (form *a*) or with 5·1 and 4·1 with a pale spot (form *b*). Vein 3 usually extensively pale with small dark spots at base, but in certain series liable to be extensively or completely dark (*leptomeres*).

Male palpi having the club with pale apex, a moderate sized pale spot about the middle and a pale area at the base.

Larva.—Fronto-clypeal pattern without a separate transverse bar anteriorly, the posterior dark spot joined to remainder of pattern by a narrow isthmus. All clypeal hairs simple unfrayed; inner sutural hair *branched;* tergal plates on segments 3-7 not including the two small oval plates ; hair 0 not arising from tergal plate, with 2-5 branches (Puri, 1931).

Egg.—Dorsal surface at least as broad as the portion of ventral surface lying between the frill and float, commonly divided into two oval areas. Floats occupying about the middle three-quarters of the egg with at least $\frac{1}{8}$ of the egg length intervening between the termination of the float and the ends of the egg ; float ridges narrow, somewhat crowded together, longer in length than in breadth, not giving the square cellular appearance characteristic of the egg of *A. aconitus* (Christophers and Barraud, 1931).

Habits.—Breeds especially in pools in stream and river beds.

Distribution.—Specimens have been seen by us from : BURMA : *N. Shan States,* Kalaw. ASSAM : *Kamrup D.,* Nalbari. BENGAL : *Jalpaiguri D.,* Marianbari ; *Darjeeling D.,* Siliguri. BIHAR AND ORISSA : *Singhbhum D.,* Duia,

* As pointed out by one of us (S. R. C.) in 1924 the name *listonii* is really preoccupied. The name *fluviatilis* is now employed by Edwards.

† The uninterrupted dark area in the basal portion of the costa is very characteristic of this species and *A. varuna ;* only extremely rarely is an interruption sometimes seen in the former species.

Chiria, Manharpur, Unqua. MADRAS: *Vizagapatam D.*, Kolab Bridge Works, Koraput; *Bellary D.*, Sandur State; *N. Arcot*, Tirumalai Hills. *S. Arcot*, Vriddhachalam. COORG: Mercara. MYSORE: Bangalore. BOMBAY: Savantwadi State; *Belgaum D.*, Belgaum; *Poona D.*, Kirkee; *Nasik D.*, Deolali; *Thana D.*, Karjat, Andhra Valley. CENTRAL PROVINCES: Satpuras; Balaghat; Jubbulpore. CENTRAL INDIA: *Rewah State; Indore State*, Mhow. UNITED PROVINCES: *Naini Tal D.*, Kashipur, Bhowali, Banbassa, Kichha; *Saharanpur D.*, Saharanpur, Dehra Dun. KATHIAWAR: Rajkot. PUNJAB: Delhi; Karnal; *Ambala D.*, Mani Majra, Kasauli; Kapurthala State; Amritsar; *Gurdaspur D.*, Madhopur. CHAMBA: Dharmsala, Bakloh. KASHMIR: Tangmarg. N. W. F. PROVINCE: *Hazara D.*, Abbottabad; *Peshawar D.*, Risalpur, Mardan; Lundi Kotal; *Swat D.*, Malakand, Chakdara; *Kohat D.*, Kohat, Thal; *N. Waziristan*, Kotkai, Sarwakai. *S. Waziristan.*, Jandola. BALUCHISTAN: Zhob D., Fort Sandeman, *Quetta Peshin D.*, Quetta.

A. minimus Theobald, 1901.

A. christophersi Theobald, 1902.
A. formosaensis Tsuzuky, 1902.
A. cohaesa Donitz, 1903.
A. mangyana Banks, 1906.
A. alboapicalis Theobald, 1910.
A. flavirostris Ludlow, 1913.
A. febrifera Banks, 1914.
A. merak (*cohaesa*) Mankoewinot, 1919.
A. funestus of Christophers and Stephens, 1902, Banks, Ludlow and in part of Strickland, Carter and others. *Nec.* Giles.

Female palpi with broad subapical band, the intervening dark band usually less than twice the length of the subapical pale band and never more than ⅓ (often ¼ or less) the length of the dark area between the subapical and basal band. No pale fringe spot at termination of vein 6. Base of costa very constantly *with* a pale interruption or some indication of such, if only a pale scale or two on perhaps one wing. Proboscis dark, or commonly with a small flavescent tache on the ventral aspect only and rather characteristically narrowly crescentic on lateral view.

Vein 6 dark in outer half. Vein 4·1 and vein 5·1 beyond cross-vein usually with pale spots. Vein 3 usually extensively pale but with dark areas towards base. Fore and mid tarsi commonly showing distinct indication of narrow tarsal banding.

Male palpi with pale apex and a considerable area of middle portion of club pale leaving a narrow black basal band only as the club is viewed from above and with a well marked pale spot at junction with shaft.

Larva.—Fronto-clypeal pattern without separate transverse bar anteriorly, the posterior dark spot joined to remainder of pattern by narrow isthmus. All clypeal hairs simple, unfrayed; the inner sutural hair *branched;* tergal plates not including the small oval plates; hair 0 not arising from the plate, simple or bifid (Puri, 1931).

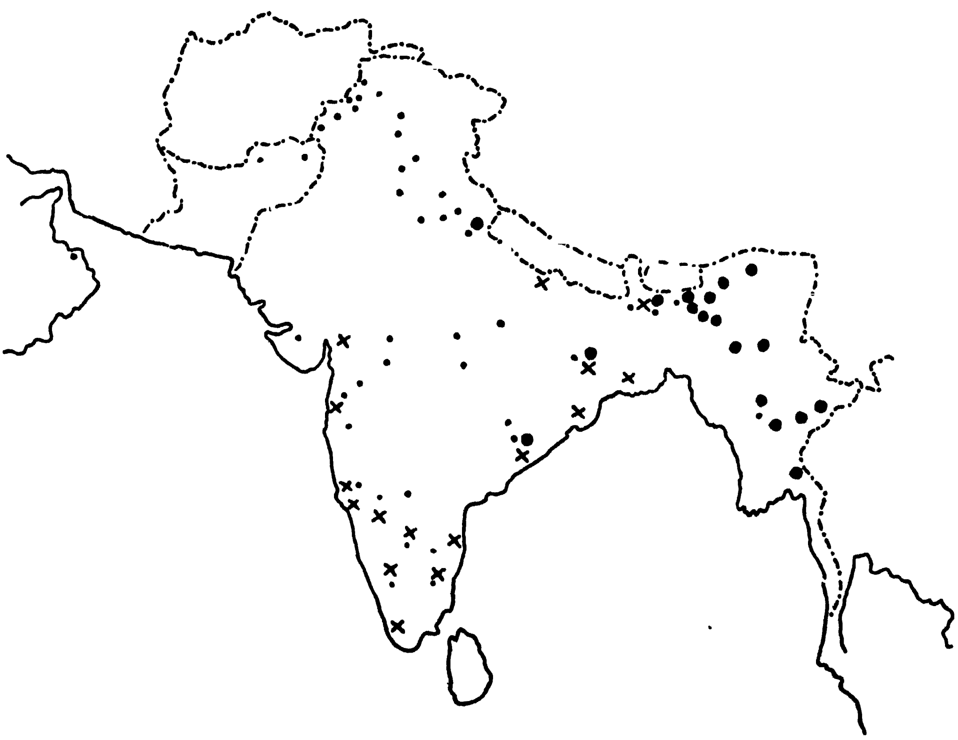
Egg.—Undescribed.

Habits.—Breeds in flowing water or pools in stream beds.

Distribution.—Specimens of this form have been seen by us from: PHILIPPINES; Novatiches, Manilla. FORMOSA. BURMA: *Salween D.*, Papun; *S. Shan States*, Shwenyaung, Namtu; *Yamethin D.*, Delangyun; *Mandalay D.*, Maymyo; *Upper Chindwin D.*, Mawlaik; *Katha D.*, Katha. ASSAM: *Sibsagor D.*, Mariani; *Nowgong D.*, Solana, Lumding; *Kamrup D.*, Gauhati, Nalbari; *Khasi and Jaintia Hills D.*, Shillong, Nongpoh; *Cachar D.*, Laboc. BENGAL: *Jalpaiguri D.*, Marianbari, Raja Bhat Khawa, Meenglas. BIHAR AND ORISSA: *Singhbhum D.*, Duia, Unqua, Chiria. MADRAS: *Vizugapatam D*, Kolab Bridge Works. UNITED PROVINCES: *Naini Tal D.*, Banbassa, Kichha.

A. varuna Iyengar, 1924.

Female palpi with broad subapical band, the dark intervening area less than ⅓ the length of the more basal dark area. No pale fringe spot at vein 6. Base of costa *without* an interruption or any indication of such. Proboscis uniformly



TEXT FIGURE 2.

Map of India and Burma showing recorded localities for *A. minimus* (larger black dots) and *A. varuna* (crosses). Verified localities for *A. listonii* are shown by small dots, one such also showing recorded locality for *A. arabica*. Only verified records the specimens of which have been examined by us are entered. Some records are omitted where they are too closely crowded.

flavescent in outer half, sometimes conspicuously so, often only faintly discernible or 'rarely' absent.

Vein 6 dark in outer half; vein 5·1 beyond cross-vein usually continuously dark, but often showing a small pale spot*; veins 2 and 4 with the branches continuously dark; vein 3 commonly about $\frac{2}{3}$ pale but rather frequently all dark. Fore and mid tarsi usually without any trace of tarsal banding.

Larva.—Fronto-clypeal pattern without separate transverse bar. Head pattern dark and not well defined; posterior spot not joined to remainder of pattern by isthmus; all clypeal hairs simple, unfrayed; inner sutural hair *branched;* small oval plates not included in anterior tergal plates; hair 0 arising from plate, simple, rather stout and short.

Egg.—Undescribed.

Habits.—Breeds in rain pools (Iyengar, 1924), also wells. This species appears to be almost as marked a well breeder as *A. stephensi.*

Distribution.—Specimens of this species have been seen by us from :—BENGAL: Calcutta; *Rangpur D.*, Saidpur. BIHAR AND ORISSA: *Singhbhum D.*, Duia, Manharpur, Unqua; *Cuttack D.*, Cuttack. MADRAS: *Vizagapatam D.*, Vizagapatam; *South Arcot D.*, Vriddachalam; *Chingleput D.*, Ennur; TRAVANCORE; COORG: Mercara. MYSORE: Bangalore, Hiriyur. BOMBAY: *Dharwar D.*, Hubli; *North Kanara*, Tellapur; *Savantwadi State;* Bombay. GUJARAT: Baroda. UNITED PROVINCES: *Gorakpur D.*, Gorakhpur.

A. aconitus Donitz, 1902.

A. albirostris Theo., 1903.

A. brahmacharii Christ., 1912.

Female palpi with broad apical band, the intervening dark band less than twice the subapical pale band and never more than $\frac{1}{3}$ (often $\frac{1}{4}$ or less) the dark area between the subapical pale band and the basal band; the intervening dark band commonly greatly reduced or altogether absent. A pale fringe spot at termination of vein 6, occasionally absent, when diagnosis must be based on other characters which usually give a clear indication. Base of costa *with* or *without* an interruption. Proboscis with the outer half or $\frac{1}{3}$ markedly flavescent, usually rather abruptly demarcated and extending completely over the apical portion of the organ uninterruptedly to labella. Tarsi often showing quite distinct narrow banding.

Vein 6 usually with three dark areas, but not infrequently continuously dark in outer half. Vein 5·1 beyond cross-vein and vein 4·1 and often 2·2 and even 2·1 with pale interruptions, or 2·2 pale in inner half of extent. Vein 3 extensively pale (very occasionally all dark) and often without any dark scales at inner end.

Larva.—Fronto-clypeal pattern without separate transverse bar anteriorly, the posterior dark spot usually linked with the rest of pattern by isthmus. Inner

* Typical specimens of this species including all verified bred specimens are dark winged. Some specimens with much lighter wing markings may possibly be erroneously identified (i.e., *aconitus* without a fringe spot).

and outer anterior clypeal hairs frayed or with short lateral branches, posterior clypeals branched from base. Inner sutural hair *branched*, 4-6 branches; the small oval plates not included in the anterior tergal plate; hair 0 not arising from plate, but very near edge (Puri, 1931).

Egg.—Dorsal surface narrow, slit-like, narrower than the area of ventral surface lying between the frill and the float. Floats approaching almost to ends of egg; the float ridges about as broad as long and few in number appearing more or less square from above and cell-like.

Habits.—Breeds in grassy edges of slowly flowing water.

Distribution.—Specimens of this form have been seen by us from: SIAM. SUMATRA. FEDERATED MALAY STATES. BURMA: *Akyab D.*, Akyab; *S. Shan States*, Shwenyaung; *Bhamo D.*, Bhamo. ANDAMANS. ASSAM: *Nowgong D.*, Lumding; *Kamrup D.*, Gauhati, Nalbari; *Cachar*, Labac. BENGAL: *Jessore D.*, Bongaon; 24 *Parganas D.*, Kanchrapara; Calcutta; *Nadia D.*, Khoksa; *Rangpur D.*, Saidpur. BIHAR AND ORISSA: Balasore. MADRAS: *Vizagapatam D.*, Vizagapatam, Jeypore. MYSORE: Hiriyur. HYDERABAD: Ramkote. CENTRAL PROVINCES: Jubbulpore. CEYLON.

A. filipinae Manalang, 1930.

Female palpi as in *A. aconitus*. Base of costa *with* or *without* an interruption. Fringe spot present at termination of vein 6. Proboscis dark without any flavescent area.

Vein 6 commonly shows three dark areas. Vein 5·1 and vein 4·1 with pale interruptions.

Larva.—Clypeal hairs of larva frayed or branched (Manalang, 1930).

Distribution.—Philippine Islands. A series of what appears to be this form was sent as *A. minimus* some time ago to the Bureau by Dr. Tiedemann.

The following table gives some of these characters for the Oriental forms in a synoptic arrangement.

1. Female palpi with narrow subapical band, the dark area between the apical and subapical pale bands at least twice the length of the subapical pale band and not less than a third and often a half or more that of the dark area between the subapical pale band and the more basal band. Hair 0 in larva with 2–5 branches. No fringe spot at 6; base of costa without interruption or any trace of such; proboscis entirely dark except labella .. .. *A. listonii.*
   Female palpi with broad subapical band, the dark area not more than twice the subapical pale band, often about equal or less, and one-third or less the dark area between the subapical pale band and the more basal band. Hair 0 in larva simple or bifid .. .. 2.
2. Without a fringe spot at termination of vein 6. Vein 6 usually uninterruptedly dark in outer half. Clypeal hairs of larva simple .. .. .. 3.
   With a fringe spot at termination of vein 6. Vein 6 usually with three dark areas. Clypeal hairs of larva branched .. .. 4.
3. Basal area of costa with a pale interruption or some indication of such (i.e., a pale scale or two). Proboscis all dark or with a short narrow crescentic tache ventrally. Hair 0 of larva not arising from anterior tergal plate .. *A. minimus.*

Basal area of costa without a pale interruption or any indication of such. Proboscis usually with faint to moderate or more conspicuous flavescence in distal half not confined to ventral aspect. Hair 0 of larva arising from anterior tergal plate .. .. *A. varuna.*
Proboscis with marked flavescence on distal half or third, sharply defined and extending to labella .. .. *A. aconitus.*
Proboscis all dark .. .. *A. filipinae.*

SYSTEMATIC POSITION OF FORMS.

That all these forms, including *A. funestus*, are very closely related is evident and under these circumstances there arises the question of the advisability of treating all the forms as varieties of one species. The egg of *A. aconitus* is, however, entirely different from that of *A. listonii*, so that these two forms at least are distinct species. Further the simple inner sutural hair and the character of the tergal plates seems to show that *A. funestus* is distinct from all the eastern forms including *A. listonii.* In none of the large number of larvae of the Indian forms examined by one of us has inclusion of the small oval plates in the anterior tergal plate ever been seen, but this character holds good in all the specimens of *A. funestus* larvae available to us. Further the simple and branched state respectively of the inner sutural hair does not seem compatible with variation except of a specific character. The origin of hair 0 from the tergal plate is not seen in *listonii* or *minimus*, but only in *A. varuna* among eastern forms. Here therefore a specific rather than a mere varietal difference appears to exist.* *A. arabica* has larval characters which do not admit of its being placed as formerly as a variety of *funestus* and though it may be a variety of *A. listonii* the very distinct wing markings and habits may indicate a distinct species. The distinction between *A. minimus* and *A. listonii* is really very clear in spite of some specimens especially from certain areas having ambiguous characters. It seems quite certain that *A. minimus* does not extend west of Delhi and so far as our observations go *A. minimus* does not extend widely into the Peninsula. Further there are small differences in the larva, notably the branching of hair 0, but also perceptibly in the proportions of the palmate hairs. If considered varieties of one species *A. minimus* would retain its name and *A. listonii*, a really invalid name, would become *A. minimus* var. *fluviatilis* James. On the whole it seems simplest, and most in accordance with what is known of these two forms, to regard them also as species. In *A. varuna* the origin of hair 0 from the tergal plate distinguishes it from all other Oriental forms and the flavescence of the proboscis is also very characteristic. Its habits also seem very distinct as it is a marked well-breeder which none of the other species appear to be. Whilst our studies of *A. filipinae* are very limited it appears to us from Manalang's work that this might well be a further nearly related but distinct species. The position therefore at present appears to us as given in our brief systematic résumé.

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* *Note.*—The difference in the eggs of course now decides this point, *A. funestus*, though it resembles *A. listonii*, is clearly quite a distinct species.

ACKNOWLEDGMENTS.

We are deeply indebted to Dr. C. B. Symes and Dr. J. I. Roberts, Medical Department, Nairobi, Kenya, for so very kindly forwarding at the request of Major G. Covell, I.M.S., a considerable number of adults and larval skins of *A. funestus* from their area. We are further greatly indebted to Dr. C. B. Symes for the eggs and corresponding adults of *A. funestus*, the former sent on blotting paper damped with formalin, under which conditions they arrived in a perfect state of preservation. Examination of these eggs, verified with the adults, has definitely shown that *A. funestus* is a distinct species from *A. listonii*.

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STUDIES ON THE RETICULO-ENDOTHELIAL SYSTEM WITH SPECIAL REFERENCE TO MALARIA.*

Part III.

THE SERUM BILIRUBIN IN MALARIA.

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1. THE RÔLE OF THE RETICULO-ENDOTHELIAL SYSTEM IN THE DESTRUCTION OF RED BLOOD CELLS.

IT seems to be generally accepted that bilirubin is derived from haemoglobin, but although this source of bilirubin appears to be undisputed, it cannot be claimed that haemoglobin is directly transformed into bilirubin. On the contrary there is much support for the belief that bilirubin is derived from certain of the disintegration products of haemoglobin. Mann, Sheard, Bollman, and Baldes (1926) have cited haematin as an intermediate product in this transformitory process, while Rich and Bumstead (1925) have shown that haematoidin, which is also an intermediate product of haemoglobin, is identical with bilirubin. Van de Velde (1927) upholds these findings and has shown that haemoglobin itself is not readily transformed into bilirubin, but that certain of its disintegration products promptly undergo this transformation.

The haemoglobin from which bilirubin is ultimately derived, becomes available as the result of destruction of red blood cells, and it is therefore necessary to refer to some of the more recent researches relating to this process of blood destruction.

It is many years since the spleen was first described as 'the graveyard of the red blood cells,' but more recent researches have shown that, although the spleen may take an active part in this process, other organs such as the bone marrow, lymph nodes, and liver may also participate, even under physiological conditions. After splenectomy and in certain pathological conditions, these other organs may display greatly increased activity in this destructive mechanism.

Kyes (1914) found that, under physiological conditions, red blood cells were destroyed by a process of active phagocytosis on the part of the endothelial cells

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of the liver and spleen. Rous and Robertson (1917), however, came to the conclusion that phagocytosis as a means of blood destruction in man, under normal conditions, was slight, and that fragmentation was the chief factor. Motohashi (1922) found that, in rabbits, phagocytosis of red blood cells by the endothelial cells of the spleen was a highly developed function, and that this function was confined to the spleen under physiological conditions. This worker further found that, after removal of the spleen, the fixed tissue phagocytes of the bone marrow and liver acquired the function of erythrophagocytosis. Karsner, Amiral, and Bock (1914) had previously noted phagocytosis of the red blood cells in the liver and lymph nodes following splenectomy, and Pearce (1918) likewise recorded the presence of engulfed red corpuscles in the phagocytic cells of the lymph nodes after splenectomy. Peabody and Broun (1925) found that, under normal conditions, phagocytosis of red blood cells occurred to a limited extent in the bone marrow and to a lesser extent in the liver, spleen, and lymph nodes, but that, under certain pathological conditions, extensive phagocytosis of red blood cells occurred in these organs, especially in the bone marrow. Doan and Sabin (1926) concluded that there is constantly some breaking down of the red blood cells by fragmentation, and that these fragments as well as whole red corpuscles, are taken up and further disintegrated by the phagocytic cells of the organs and tissues. These workers further noticed that when there was increased fragmentation of the red cells in normal or pathological conditions, the phagocytic cells increase proportionately and engulf the fragments.

The observations cited above tend to show that the process of blood destruction is accomplished, at least to some extent, through the activity of the phagocytic (reticulo-endothelial cells) of such organs as the spleen, liver, bone marrow, and lymph nodes, although under normal conditions some of these cells may not take an active part in this process. It is interesting to note that Motohashi (1922) was able to produce increased auto-erythrophagocytosis in rabbits by means of colloidal silver injections, a finding which suggests that such injections may serve to stimulate the reticulo-endothelial cells to increased erythrophagocytic activity. If it can be accepted that the reticulo-endothelial cells of the body are responsible for the destruction of red blood cells, it would not be difficult to believe that these same cells are intimately connected with the splitting up of haemoglobin, the disintegration products of which are regarded as the source of bilirubin. The evidence that such is the case will be considered below.

2. The site of formation of bilirubin.

The classical experiments of Minkowski and Naunyn (1886) from which they showed that, in geese in which the liver was removed, the severest degrees of arsenhydrogen poisoning failed to produce jaundice, led to the belief that the liver cells were solely responsible for the formation of bilirubin, a belief which held the field for many years. McNee (1913), in carrying out similar experiments, suspected that the Kupffer cells of the liver, and not the liver cells themselves, were responsible for the formation of bilirubin. Whipple and Hooper (1913) were able to show that,

in dogs, haemoglobin could be changed into bilirubin without the participation of the liver. A question which had long been regarded as settled was now reopened, for, in removing the livers of geese. Minkowski and Naunyn had deprived the birds not only of their liver cells but also of their reticulo-endothelial cells which in birds are confined almost exclusively to the liver.

Lepehne (1919) following up the conception of the recently described reticulo-endothelial system found that after 'blockade' of this system following collargol injections, there was a definite diminution in bile pigment formation in certain animals. Other workers in carrying out similar experiments were unable to confirm Lepehne's findings with the result that his observations were severely criticized, and the opinions expressed by McNee seriously questioned. Aschoff (1924) urged that the rôle of the reticulo-endothelial system in the formation of bilirubin should receive the closest attention. His belief, that the reticulo-endothelial cells were actively involved in bile pigment formation, was based on histological observations, from which he shared the views of McNee and Lepehne that the transformation of haemoglobin into bilirubin took place within the reticulo-endothelial cells, not only of the liver but also in other organs. In summarizing all that was then known about the formation of bile pigment Aschoff says with reference to experiments on dogs, 'Morphological investigations which show the first changes in toxic icterus to involve the reticulo-endothelial elements while the liver cells are entirely unaltered, confirm the opinion that the reticulo-endothelial apparatus, i.e., the splenic tissue within and without the liver, and not the liver cells, plays an important rôle in the formation of bile pigment.'

Oppenheimer (1924) was unable to demonstrate the formation of bile pigment in the isolated limb of a dog, at least within six hours, and McNee and Prusik (1924) were able to produce only a limited amount of bilirubin in a head and thorax circulation from which the liver and other organs rich in reticulo-endothelial cells were excluded.

The series of experiments of Mann and his co-workers at the Mayo Clinic has greatly advanced our knowledge of this subject, and has proved beyond doubt that there is extra-hepatic formation of bile pigment in mammals. Using an elaborate method for the removal of the liver in the dog, and keeping the animal alive, Mann, Bollman, and Magath (1924) have been able to show that a large proportion of the bilirubin excreted by the liver is of extra-hepatic origin. Rich (1925) arrived at similar conclusions. Later, Mann, Sheard, Bollman, and Baldes (1925), by means of observations on the bilirubin content of the blood entering and issuing from the spleen and bone marrow, concluded that bilirubin is formed mainly in these organs, probably by the reticulo-endothelial cells. Mann, Sheard, and Bollman (1926) further showed that hepatectomy or splenectomy, or both, had little effect on bile pigment formation, and since they found that the bone marrow was the only other site of bile pigment formation, they concluded that bile pigment is formed mainly in the bone marrow, and that the liver and spleen are minor sources. It seems possible, however, that after the removal of the liver, or spleen, or both,

the bone marrow may compensate very rapidly for the loss of these organs, and in this connection it is interesting to note that Rosenthal and Licht (1927) have recorded that, in the *intact* animal, only 20 to 33 per cent of the bile pigment was formed outside the liver.

Recently Haldeman (1929) has pursued this problem still further by means of histological methods of study. This writer assumes that the iron, liberated as the result of the breaking down of haemoglobin, serves as an indicator to the cells which have been chiefly concerned in the transformation of haemoglobin into bilirubin, or at least into a precursor of bilirubin. He has accordingly mapped out the cells which contain iron in relative abundance. Following intravenous injections of haemoglobin, he has been able to show that there is frequently a striking rise in the iron content of the reticular cells of the bone marrow, and of the stellate (Kupffer) cells of the sinusoids of the liver. Haldeman concludes from these observations that the bone marrow plays the major part in the formation of bilirubin, and that the liver and spleen, and possibly also the lymph nodes, play a minor rôle in this process. The wandering group of reticulo-endothelial cells has not escaped his attention, for the formation of bile pigment in isolated regions is attributed to the activity of the macrophages or histiocytes of the tissues.

It may, perhaps, be premature to state that it is now definitely established that the reticulo-endothelial system is the agency chiefly responsible for the destruction of red blood corpuscles, and the subsequent breaking down of haemoglobin with the ultimate formation of bilirubin, but there is undoubtedly strong evidence that such is the case. The cells of this system have vigorous phagocytic propensities, and have been shown to perform the function of engulfing fragmented, and even whole, red blood corpuscles in normal and pathological conditions. There is evidence that the haemoglobin thus ingested by the reticulo-endothelial cells is broken down within these cells into simpler substances, and that bilirubin is derived from the disintegration products of haemoglobin. The results of recent research work go to show that bilirubin is formed chiefly in those organs which are richest in reticulo-endothelial cells, and especially in those which are most active in ingesting red blood cells. These observations have recently been supported by histological studies.

3. The serum bilirubin in malaria.

In view of the strong evidence in favour of the involvement of the reticulo-endothelial system in the formation of bilirubin, it was decided to investigate the behaviour of the serum bilirubin in malaria, since, as has already been pointed out (Mulligan, 1929), there is reason to believe that this system may become extensively altered as the result of malaria infection.

Material.

Sixty bilirubin estimations were made on twenty-eight cases of malaria, of which fourteen were benign tertian, and fourteen were malignant tertian infections.

One of the benign tertian cases was also infected with malignant tertian but as the benign tertian parasites were predominant, this case has been included along with the benign tertian cases. This case of mixed infection along with the remainder of the benign tertian cases occurred in the Malaria Treatment Centre, Kasauli, among British soldiers who showed a tendency to relapse in spite of ordinary methods of treatment (*vide* Table I). The malignant tertian cases were all selected from among Indian sepoys, and in every case the infection was believed to have been freshly acquired, and the investigations were carried out in the acute stage of the disease. These cases are tabulated in Table II.

Technique.

The technique employed was the quantitative estimation of bilirubin by Van den Bergh's method as described by McNee and Keefer (1925). Two different colour standards were employed for each investigation, and the results obtained with each of these were almost identical. In recording the results the mean of the readings with each of these colour standards has been given to the nearest first place of decimals. The first colour standard was that described by McNee and Keefer (1925), namely, a solution of 2·161 grams anhydrous cobaltous sulphate in 100 c.c. distilled water. The second standard was that recently advocated by Rhamy and Adams (1927), namely, 0·7 c.c, of ripened decinormal potassium permanganate solution diluted to 50 c.c. with distilled water. Both these colour standards were kept ready in glass wedges so that one could be rapidly substituted for the other in the colorimeter. Careful attention was paid to the preparation and storage of t e colour standards as given by the respective authorities.

In a series of apparently healthy adults (both European and Indian) the serum bilirubin as estimated by this method in no case exceeded 0·6 units, and this was taken as the upper limit of normal.

Results.

The results are shown in Tables I and II. From these tables it will be seen that there was an increase above normal in the serum bilirubin of every case of malaria examined, where the estimations were made in the early stages of the attack and before treatment was commenced. In two cases (Table II, cases 1 and 12) there was a further slight rise in the bilirubin readings immediately after the exhibition of quinine treatment, the estimations in both these cases being made within twenty-four hours of the commencement of treatment. The number of cases examined is too small to attempt to correlate the quantity of serum bilirubin with any of the clinical manifestations of the disease, but it will be seen from a glance at the tables that there was a definite tendency for the serum bilirubin to return towards normal proportions in all the malaria cases examined, after treatment had been instituted. From these investigations it would appear that, in the early stages of malaria infection, there is a well defined increase in bilirubin content of the serum. This increase may

be accentuated immediately after quinine has been administered. Subsequently there is a gradual fall in the bilirubin content of the serum until, after six or seven days from the onset of the attack, more or less normal proportions are approximated in treated cases.

These results confirm the findings of Kingsbury (1926) and Ross (1927), both of whom found that there was a practically constant increase in the serum bilirubin in malaria especially in malignant tertian cases.

Discussion of results.

The indirect Van den Bergh reaction, which can be shown to occur with remarkable constancy in malaria, indicates, on the theory of the causation of jaundice put forward by McNee (1924), that the type of jaundice (latent or apparent) which occurs in malaria is of the haematogenous variety. This signifies the occurrence of (*a*) excessive blood destruction, (*b*) formation of bilirubin by the reticulo-endothelial system in excess of that with which the polygonal cells of the liver can deal, or (*c*) a combination of both these processes.

There is undoubtedly excessive blood destruction in malaria. Craig (1909) says, 'in no disease is the destruction of the red corpuscles more rapid than in malaria.' He quotes various authorities as having shown that the total red cell count may fall as much as one million in a day, or even two million in two days. Other writers [Machiafava and Bignami (1900); Deaderick (1911); Laveran (1907), Mannaberg (1905)] are equally emphatic about the great and rapid destruction of the red blood cells in malaria.

This excessive loss of erythrocytes is, in a large measure, due to 'mechanical' destruction of the red corpuscles at the time of segmentation of the parasites, but may to some extent be accounted for by other processes. There can be little doubt that phagocytosis of red blood corpuscles is a factor in the process of blood destruction in malaria. It has been a common observation that the same cells which engulf malaria pigment (that is the reticulo-endothelial cells) also ingest red blood cells, either alone or with malaria parasites still attached. They probably also ingest fragments of red blood cells which have been broken down as the result of 'mechanical' destruction. In this connection it is interesting to refer to the experiments of Motohashi (1922) in which he showed that, in rabbits, the function of auto-erythrophagocytosis of red blood corpuscles was considerably increased following injections of colloidal silver. The probability is that the colloidal silver served as a stimulating agent on the reticulo-endothelial system of the rabbit, thereby increasing the phagocytic propensities of the cells of which this system is comprised. It seems probable that malaria pigment might act in a similar manner on the reticulo-endothelial cells. There is yet another factor which must be considered in relation to blood destruction in malaria, namely, the action of specific haemolysins. The evidence in favour of this being an important factor is not very convincing. Simpson (1912) produced some evidence to show that there was some degree of haemolysis in blood drawn from malaria patients during schizogony,

while there was none in the normal controls. Thomson (1924) noted that 'if the blood was drawn at a period corresponding to schizogony in the body, haemolysis invariably took place in the tubes.' This writer also quotes Orpen as having 'obtained some evidence that again a haemolysin was present at this stage.' Kingsbury (1926) states that he has noted that 'marked haemolysis may occur in cultures of *P. falciparum*.' Brown (1913) expressed the opinion that malarial haematin is, on account of its toxicity, responsible for destruction of red blood cells in malaria.

However it may be brought about there is no doubt that there is increased destruction of red blood cells in malaria. According to Doan and Sabin (1926) increased fragmentation of red blood cells, in pathological conditions, is followed by a compensatory hypertrophy of the clasmatocytes (reticulo-endothelial cells) not only of the organs but also of the blood. If this is the case one would expect to find such an hypertrophy in malaria. Kingsbury (1926) has shown that in malaria the degree of bilirubinaemia goes hand in hand with the size of the spleen, and this writer was the first to suggest that the enlargement of the spleen in malaria may be connected with hypertrophy of the reticulo-endothelial cells required to deal with increased blood destruction in untreated malaria infections. In view of the work of Doan and Sabin referred to above this explanation seems quite feasible, though it must be remembered that in malaria the reticulo-endothelial cells are called upon to deal with malaria pigment (haemozoin) as well as with fragmented and whole red blood cells. It would therefore appear to be equally plausible to assume that there is a compensatory hypertrophy of the reticulo-endothelial cells in malaria in order to deal with the 'foreign' material present in the blood stream after segmentation of the parasites. Doses of 'foreign' material which are insufficient to produce the so-called 'blockade' of the reticulo-endothelial system, are believed to act as stimulating agents on this system. It seems rational to assume that such a stimulation follows the liberation of malaria pigment and parasites into the blood stream, and that one of the results of this stimulation is to be seen in the increased haemophage activity of the reticulo-endothelial cells, in a manner similar to that which can be experimentally produced in rabbits after experimental injections of colloidal silver (Motohashi, 1922).

With regard to the participation of the reticulo-endothelial cells of the peripheral blood in blood destructive processes in malaria it may be recalled that the work recorded in Part II of this series of papers (Mulligan, 1929) throws some light on this point. According to Sabin and Doan (1926) the monocytes of the blood were found to give a positive peroxydase reaction only after they had ingested peroxydase reacting material, and in their experiments they noted fragmented red blood cells gave this reaction after their ingestion by the monocytes. In Part II of this series, referred to above, it was found that the monocytes in the peripheral blood in malaria, in the majority of instances, gave a positive peroxydase reaction. It is thought that this finding may be accounted for by the ingestion of fragmented red blood cells by the monocytes.

TABLE I.

Case No.	Disease.*	Parasites.	Spleen.†	Bilirubin units before treatment.	Bilirubin units on days of quinine treatment.						
					1	2	3	4	5	6	7
1	B. T. ..	+	2F	2·4	..	1·8	..	..	0·9	..	..
2	B. T. ..	+	nil	1·3	..	..	..	..	..	0·6	..
3	B. T. ..	+	nil	1·5	..	..	..	..	..	0·6	..
4	B. T. ..	++	P.	2·8	..	..	1·4	..	0·8	..	..
5	B. T. ..	+	nil	..	..	..	..	..	..	..	0·4
6	B. T. ..	+	nil	..	..	..	..	..	..	0·5	..
7	B. T. ..	++	nil	..	..	1·3	..	..	..	..	0·4
8	B. T. + M. T.	+	P.	1·8	..	..	..	0·8	..	..	..
9	B. T. ..	+	1F	1·5	..	..	0·8	..	..	..	..
10	B. T. ..	+	P.	1·2	..	..	..	..	0·7	..	..
11	B. T. ..	+	2F	..	1·5	..	..	..	..	0·5	..
12	B. T. ..	++	2F	..	1·4	..	..	..	..	0·6	..
13	B. T. ..	+	P.	2·0	..	1·1	..	..	..	..	..
14	B. T. ..	+	P.	..	..	1·4	..	..	0·6	..	..

* B. T. means benign tertian malaria (*P. vivax*).
M. T. means malignant tertian malaria (*P. falciparum*).
† 'Nil' indicates that the spleen was not palpable.
'P' indicates that the spleen was just palpable.
'1F' indicates that the spleen was enlarged one finger breadth below the costal margin.
'2F' indicates that spleen was enlarged two finger breadths.
'3F' indicates that spleen was enlarged three finger breadths.

TABLE II.

Case No.	Disease.*	Parasites.	Spleen.*	Bilirubin units before treatment.	Bilirubin units on days of quinine treatment.						
					1	2	3	4	5	6	7
1	M. T. ..	Scanty	nil	1·8	1·9	..	..	..	..	..	0·8
2	M. T. ..	+	nil	1·2	..	..	..	..	0·5	..	..
3	M. T. ..	+	3F	3·2	..	..	1·1	..	..	..	..
4	M. T. ..	+	2F	1·4	..	..	..	0·8	..	..	..
5	M. T. ..	++	1F	0·9	..	..	..	..	..	0·6	..
6	M. T. ..	++	nil	1·6	..	..	..	..	0·7	..	..
7	M. T. ..	++	3F	2·0	..	1·6	..	..	..	..	..
8	M. T. ..	++	P.	1 2	..	..	..	.	0·4	..	..
9	M. T. ..	+	P.	0·8	.	..	0·6	..	..	..	..
10	M. T. ..	+++	P.	2·4	..	..	1 3	..	..	..	..
11	M. T. ..	+	nil	1·4	..	..	..	..	0 7	..	..
12	M. T. ..	++	nil	1·0	..	..	..	0·6	..	..	..
13	M. T. ..	++	P.	2·7	..	..	1·2	..	..	..	..
14	M. T. ..	++	P.	3·5	..	2·1	..	..	1·3	..	..

* *See* foot-note Table I.

Manson-Bahr and Sayers (1927) and Ross (1927) appear to agree with Kingsbury's (1926) view that there may be hypertrophy of the reticulo-endothelial system in malaria. Ross (1927) found that, in blackwater fever, the reticulo-endothelial system was capable of producing bilirubin in very large amounts, in every case in excess of that found in malignant tertian malaria. Since the evidence points to the occurrence of black-water fever almost exclusively in cases of chronic malaria (whether latent or manifest) it would be expected that there

would be considerable hypertrophy of the reticulo-endothelial system resulting from repeated stimulation of this system by the haemozoin, etc., liberated into the blood stream at the time of the recurring attacks; or, by the repeated attempts to meet the demand for increased phagocytosis of red blood cells, either whole or fragmented, which are circulating in the blood stream as effete material at this time.

Summary.

The literature relating to the mechanism of destruction of red blood cells, and the formation of bilirubin has been reviewed. There is strong evidence in support of the belief that the cells of the reticulo-endothelial system play an important part in completing the destruction of erythrocytes. Under certain pathological and experimental conditions the activity of these cells in this direction may be considerably enhanced, and it has been shown that the phagocytic cells of such organs as the liver, spleen, bone marrow, and lymph glands may be actively involved in this destructive process, though under normal conditions all these phagocytic cells may not take an active part.

Recent research work tends more and more to implicate the cells of the reticulo-endothelial system as the agency responsible for the formation of bilirubin. The cells of this system not only engulf fragmented and effete erythrocytes, but are also responsible for the subsequent elaboration of bilirubin from the disintegration products of haemoglobin which are formed within these cells.

The behaviour of the serum bilirubin in active malaria cases (both fresh and relapse cases) has been studied, and the results show that there is a well defined increase in the quantitative estimations of serum bilirubin in the early stages of the attack. This increase undergoes a gradual decline, in treated cases, until by the fifth or sixth day normal proportions are approximated.

The significance of these findings has been discussed. An increase in the serum bilirubin (indirect Van den Bergh reaction) indicates, as pointed out by McNee (1924), that there is (*a*) excessive blood destruction, or (*b*) formation of bilirubin by the reticulo-endothelial system in excess of the handling capacity of the polygonal cells of the liver, or (*c*) a combination of both these processes.

There is undoubtedly excessive blood destruction in malaria due, in a large measure, to 'mechanical' destruction of the red blood cells at the time of segmentation of the parasites. It is believed that the reticulo-endothelial system, in malaria, is stimulated to a compensatory hyperactivity in order to remove the excess of fragmented red cells present in the blood stream in an acute attack, as has been shown to occur by Doan and Sabin (1926) in other conditions where there is increased fragmentation of erythrocytes. Further it is believed that the malaria pigment (haemozoin), which is taken up by the reticulo-endothelial cells, may stimulate these cells to excessive haemophage activity in a manner similar to that which has been shown by Motohashi (1922) to occur in rabbits following injections of colloidal silver.

The explanation is offered that the increase above normal in the serum bilirubin, in the early stages of an acute malarial attack, is attributable to hyperactivity of the cells of the reticulo-endothelial system, in the presence of increased blood destruction. Conversely the decline in the bilirubin content of the serum, in treated cases, is probably due to a gradual cessation of this hyperactive function of the reticulo-endothelial cells in conjunction with a discontinuance of mechanical fragmentation of the red cells.

Conclusions.

From the foregoing considerations it would appear that :—

(1) The reticulo-endothelial system plays an important part in the ultimate destruction of red blood corpuscles.

(2) The cells of the reticulo-endothelial system are responsible for the disintegration of haemoglobin, and the subsequent elaboration of bilirubin.

(3) The serum bilirubin shows an increase above normal in the early stages of an acute malarial attack. In treated cases this increase undergoes a gradual decline until, by the fifth or sixth day of the attack, normal proportions are approximated.

(4) This increase in the serum bilirubin in malaria is determined by a combination of two factors :—

(*a*) Excessive destruction of erythrocytes, and

(*b*) Hyperactivity of the reticulo-endothelial cells.

(5) Excessive destruction of erythrocytes in malaria is largely due to 'mechanical' destruction of red cells at the time of segmentation of the parasites, but may also, to some extent, be accounted for by other factors, including an increased haemophage activity of the reticulo-endothelial cells.

(6) Hyperactivity of the reticulo-endothelial cells may be brought about by :—

(*a*) Stimulation of the reticulo-endothelial cells following ingestion of haemozoin, which acts on this system in a manner similar to other particulate substances.

(*b*) Compensatory hyperactivity of the reticulo-endothelial cells in order to deal with the excess of fragmented and effete erythrocytes present in the blood stream after segmentation of the parasites.

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MALARIA IN SIND.

Part IV.

MALARIA IN NAWABSHAH DISTRICT.

BY

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INTRODUCTION.

Parts I, II and III of this series of papers appeared in *Records of the Malaria Survey of India,* Vol. I, Part 4, in December, 1930. In the case of the present paper, as in those which have already appeared, the senior author wishes to emphasize the fact that the actual field observations which form the basis of the paper were entirely the work of Subedar J. D. Baily, I.M.D.

Previous survey.

During the months of October and November, 1913, De Sousa (1914) visited certain villages in the talukas of Sakrand, Shahdadpur and Sinjhoro. He found a splenic index of 62 and a parasite index of 20 among 930 children examined, as against figures of 70 and 15 respectively in Hyderabad District.

Period of the present survey.

The observations were carried out from December 22, 1928, to January 17, 1929, i.e., at the end of the malaria season.

Tract surveyed.

The localities visited were situated in the following talukas of Nawabshah district:—

Naushahro,
Moro,
Sakrand,
Nawabshah,
Shahdadpur.

General character of tract.

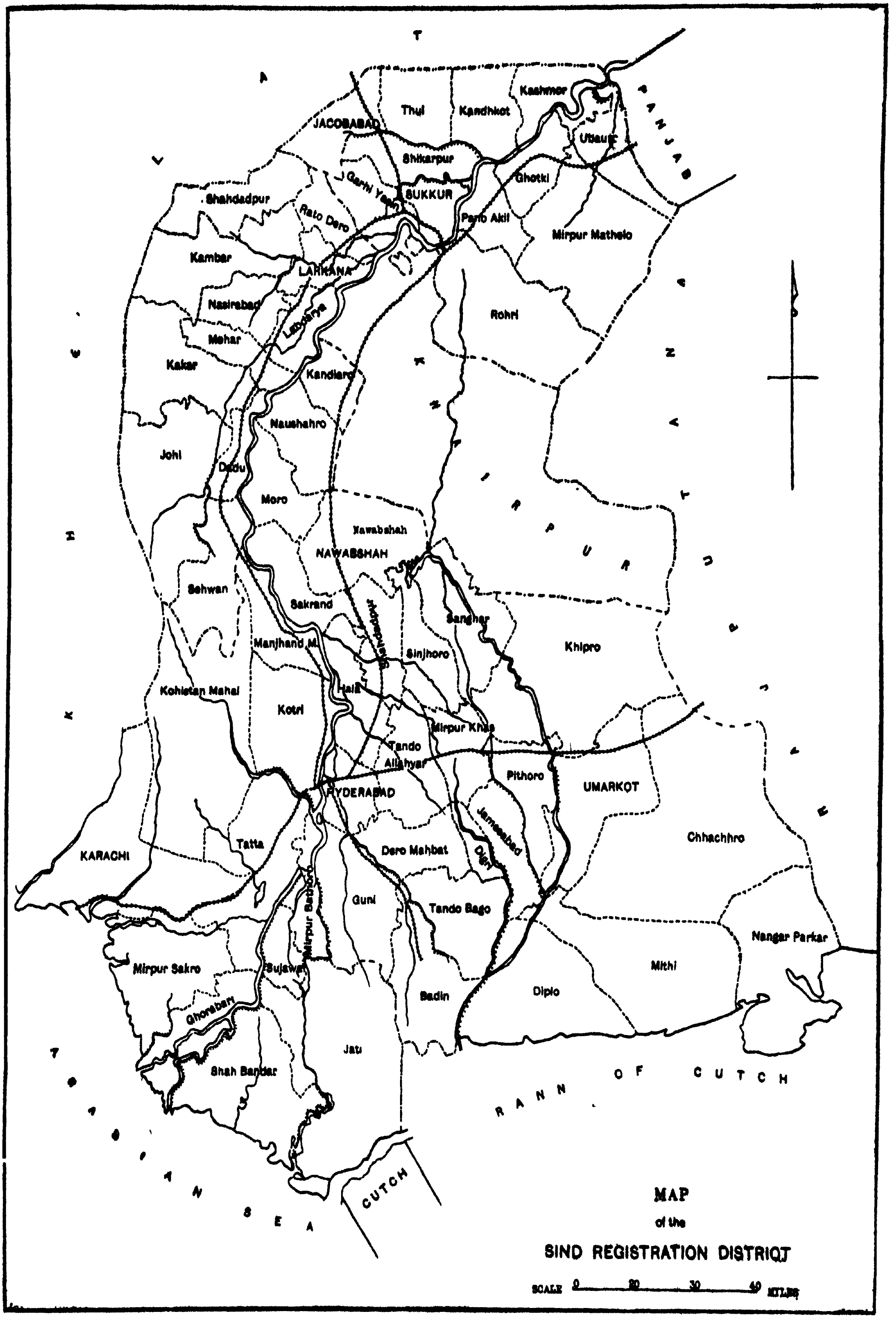
Nawabshah district is situated on the left bank of the river Indus, between 27° 50′ and 25° 45′ North latitude and 67° 50′ and 69° 5′ East longitude. It is bounded on the north by Khairpur State, on the east by the same State and Thar and Parkar district, on the south and south-west by Hyderabad district, and on the west by the river Indus. The area of the district is 3,889 square miles; its greatest length from north to south is 104 miles, and its greatest breadth from east to west 64 miles (*see* Map).

The district consists of two divisions, viz., Naushahro, comprising Kandiaro, Naushahro, Moro and Sakrand talukas, and Nawabshah, comprising Nawabshah, Sinjhoro and Shahdadpur talukas. The talukas of Naushahro are situated in the immediate neighbourhood of the river, the bank of which for a distance of three to four miles is covered by a thick forest of *Babul* trees (*Acacia arabica*), which becomes flooded every year during the inundation period. The tract of land immediately to the east of this, lying as it does at a comparatively high level, is not subject to general flooding; but almost midway between the eastern and western boundaries of the northern portion of the division there lies a belt of 'dhoros' (channels), ravines, mounds and low sand hills, running from north to south, which marks the course of a former bed of the Indus. Further south, this belt runs along the western edges of Nawabshah and Shahdadpur talukas. This part of the country is liable to flooding should the river bank in Kandiaro become breached, which may occur when the river level at Bukkur gauge exceeds 15 feet.

The villages visited in Naushahro, Moro and Sakrand talukas are all within 10 miles of the river Indus. Those visited in Nawabshah and Shahdadpur talukas lie for the most part from 15 to 25 miles distant from the river. The eastern part of the district, towards the desert area, was not visited, the portion surveyed lying wholly within the valley of the Indus.

Cultivation.

With the exception of the desert portion of Nawabshah taluka (which was not included in the present survey), the land is high-lying, and the agricultural conditions do not vary greatly in different parts. The main summer crops are



MAP
of the
SIND REGISTRATION DISTRICT

juari and bajri, and the main winter crop is wheat. Jambho (oil-seed) is also grown extensively in certain areas. A little cotton and rice are grown in Naushahro taluka. Cotton is also grown in Nawabshah and Shahdadpur talukas, and in the latter there is a little rice cultivation as well.

Irrigation.

The canals irrigating the district are almost exclusively inundation canals coming off from 'dhands' (backwaters) of the river Indus. Most of them have head regulators. The Nasrat Canals District lies wholly in Nawabshah district, but some part of the Hyderabad Canals District also irrigates it. Sinjhoro taluka (not included in the present survey) is irrigated by branches of the Jamrao Canal, a perennial canal which takes off from the Eastern Nara. Considerably more than half the tract under review is irrigated by lift, the remainder by flow. Under the Sukkur Barrage Scheme the whole of Nawabshah district will be irrigated from the great Rohri Canal, which is now under construction.

Climate.

Climatically the district is divided sharply by a line running from Sehwan Ferry eastwards to the Gango Thar opposite Daur railway station. To the south of this line, throughout the six hot months of the year, a strong steady sea breeze blows for a great part of every day and the whole of every night, its usual direction being south by west. To the north of this line the breeze disappears, and the climate has the full rigor of the Upper Sind hot weather. The maximum temperature at Nawabshah is approximately 114°F., and the minimum 48°F.

Rainfall.

The annual amount of rainfall recorded at the headquarters of the different talukas for the months of July, August and September during the period 1901 to 1930 is shown in Table I. The rainfall at Nawabshah shows a normal mean of 6 36 inches per annum, but the four northern talukas receive rather less than do the southern ones. The cold weather rains, which are so useful for the winter crops of Upper Sind, are very infrequent. Frost in the district is practically unknown.

Epidemic malaria.

As was pointed out by Young and Majid (1930), epidemics of malaria occur in Sind from time to time, usually with their centre in Upper Sind, where they appear to exhibit approximately a ten-year periodicity. The same observers noted that the coincidence of high river levels with unusual rainfall is particularly liable to be followed by an outbreak of malaria in epidemic form.

TABLE I.

Taluka rainfall figures, Nawabshah District.

Years.	Kandiaro.			Naushahro.			Moro.			Sakrand.			Shahdadpur.			Sinjhoro.			Nawabshah.			Remarks.
	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	
1901	1·35	..	..	1·73	1·50	..	0·94	0·65	..	0·39	..	..	1·20	..	..	..	..	..	..	..	..	
1902	..	1·10	0·14	..	2·52	5·60	..	1·45	3·27	1·23	2·14	0·94	0·63	0·90	1·92	..	..	..	..	..	..	
1903	2·34	..	..	1·38	..	..	2·16	..	0·20	4·72	..	..	0·85	..	..	..	..	..	..	..	..	
1904	..	..	..	..	..	..	..	..	..	..	..	1·78	..	..	..	..	..	..	..	..	..	
1905	..	..	0·33	..	..	0·01	0·61	..	0·18	0·34	..	..	0·45	..	..	..	..	..	..	..	..	
1906	..	..	0·87	..	1·03	..	..	3·29	0·22	0·22	1·35	0·13	..	1·65	0·25	..	..	..	..	..	..	Epidemic, Upper Sind.
1907	0·22	2·57	..	0·37	3·76	..	0·35	1·43	..	0·77	3·55	..	0·62	3·30	..	..	..	..	..	..	..	
1908	2·53	0·21	..	1·71	0·03	..	0·34	0·18	..	3·23	1·45	..	6·96	2·10	..	..	..	..	..	..	..	
1909	0·94	..	..	2·98	0·07	..	2·83	0·03	0·08	4·60	0·05	0·23	2·45	1·57	0·96	..	..	..	..	..	..	
1910	2·64	..	..	2·94	0·37	..	4·34	0·31	..	5·07	1·93	..	3·03	1·47	0·10	..	..	..	..	*..	..	
1911	..	1·55	..	..	1·55	..	..	1·06	..	..	..	..	..	..	..	..	..	..	..	..	..	
1912	1·19	0·94	0·40	1·92	1·03	..	2·17	3·59	..	0·47	0·91	..	2·57	1·74	..	..	..	..	..	..	..	
1913	1·47	0·61	..	4·00	0·60	0·03	4·10	0·70	1·10	11·40	2·12	0·75	8·97	0·55	1·80	7·25	0·72	2·31	11·50	3·18	0·68	
1914	2·34	..	0·07	0·73	..	0·32	10·70	..	0·38	0·74	..	0·24	1·12	..	..	1·61	..	..	0·73	..	0·06	
1915	0·30	..	0·65	0·22	..	0·07	0·35	..	0·14	0·42	..	0·31	0·62	..	0·40	0·50	..	..	0·70	..	0·38	

Table I—*concld.*

Years.	Kandiaro.			Naushahro.			Moro.			Sakrand.			Shahdadpur.			Sinjhoro.			Nawabshah.			Remarks.
	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	
1916	..	3·58	..	0·20	2·85	..	0·16	14·95	..	0·80	21·44	..	0·51	8·67	0·26	2·34	8·80	0·64	0·39	17·88	0·11	Epidemic, Lower Sind.
1917	..	6·95	9·11	..	9·59	9·08	..	10·20	6·73	0·33	11·23	7·44	0·02	9·92	4·77	0·17	9·35	4·86	0·72	8·86	0·71	Epidemic, Upper Sind.
1918	..	..	..	..	0·35	..	..	..	..	..	0·33	..	..	0·38	..	..	0·63	..	..	0·07	..	
1919	1·55	0·01	..	1·88	0·35	..	1·80	0·01	..	1·25	0·43	..	2·35	0·11	..	1·84	0·17	..	1·42	0·12	..	
1920	0·40	..	..	0·30	0·09	..	0·03	..	..	0·27	..	..	..	..	..	..	0·30	..	0·22	..	..	
1921	0·90	0·22	0·72	0·89	1·49	0·37	4·33	..	0·67	6·29	0·94	2 34	3·28	1·88	1·67	3·64	2·03	0·52	2·10	0·37	0·58	
1922	..	0·71	0·11	..	0·18	0·80	0·16	0·10	0·01	0·20	2·90	0·31	0·03	2·30	0·16	0·20	1·34	0·14	..	2·06	0·47	
1923	0·60	0·45	..	0·92	..	..	1·10	..	..	0·08	2·95	..	..	0·15	..	0·05	1·06	..	..	0·19	..	
1924	0·25	1·05	1·72	1·63	..	3·20	0·88	...	3·94	2·06	..	10·75	3·08	0·07	6·74	2·88	0·46	2·27	2·72	..	6·93	
1925	5·31	1·60	..	1·74	0·28	..	2·50	0·40	..	1·80	3·23	..	0·14	2·51	..	2·94	1·00	..	0·69	0·75	..	
1926	..	0·28	..	0·39	..	..	..	2·37	..	..	1·67	..	..	0·81	..	..	0·35	..	..	0·63	..	
1927	0·60	..	..	2·06	..	..	2·02	..	..	5·39	..	..	5·81	1·25	0·22	5·34	0·56	0·20	3·59	0·20	..	
1928	0·64	0·58	..	0·32	..	0·01	0·04	0·04	..	..	0·04	..	0·26	0·71	..	0·85	2·62	..	0·26	0·10	..	
1929	6·63	3·71	..	7·35	6·22	..	8·57	7·80	..	14·38	10·74	..	15·04	12·82	..	18·37	9·17	..	15·58	9·17	..	Epidemic, Upper Sind.
1930	2·51	0·02	..	0·80	0·08	..	2·10	..	..	7·52	0·02	..	4·41	..	..	1·48	0·10	..	2·23	0·38	..	

TABLE II.

Taluka epidemic figures, Nawabshah District.

Years.	Kandiaro.	Naushahro.	Moro.	Sakrand.	Nawabshah.	Shahdadpur.	Sinjhoro.	REMARKS.
1901	3·98	2·31	1·72	3·82	..	3·76	..	
1902	2·41	3·32	1·94	2·31	..	2·16	..	
1903	2·87	2·84	2·33	2·84	..	2·36	..	
1904	1·69	2·62	1·67	1·46	0·13	1·22	..	
1905	1·93	4·20	1·65	2·32	0·06	1·93	..	
1906	5·10	4·25	4·62	4·05	1·46	3·78	..	Epidemic, Upper Sind.
1907	1·92	1·82	2·09	1·84	0·96	1·91	.	
1908	3·42	3·65	1·91	1·82	1·22	1·62	.	
1909	1·75	1·74	1·94	2·36	1·60	1·14	..	
1910	2·00	2·36	1·62	1·55	0·63	2·61	.	
1911	1·27	1·21	0·92	0·89	0·60	1·04	..	
1912	1·64	1·97	1·22	0·66	0·86	1·26	..	
1913	3 92	2·11	1·22	2·22	2·00	1·26	1·53	
1914	2·92	1·65	1·07	0·80	1·33	1·35	0·90	
1915	2·28	2·49	1·22	1·15	1·86	2·32	2·42	
1916	6·85	3·32	3·27	2·78	2·53	4·05	3·32	Epidemic, Lower Sind.
1917	10·85	6·35	8·45	8·85	8·70	5·34	3·18	Epidemic, Upper Sind
1918	..	..	..	..	..	..	..	
1919	..	..	..	..	..	..	..	
1920	1·25	0·96	0·87	0·60	0·86	1·00	0·59	
1921	1·93	1·19	0·80	1·00	1·20	0·71	1·02	
1922	1·45	1·30	0·91	1·33	1·30	0·78	1·44	
1923	1·63	0·80	1·11	1·35	1·23	0·85	1·67	
1924	1·10	3·50	2·80	0·20	3·10	1·96	1·97	
1925	1·79	1·74	1·62	1·11	1·16	0·84	0·90	
1926	2·68	1·78	1·00	1·77	3·46	2·52	3·34	
1927	2·34	0·05	1·12	0·51	1·50	1·01	1·62	
1928	2·04	1·05	1·00	1·37	1·00	1·17	1·07	
1929	8·75	4·05	2·78	2·64	4·70	1·98	1·00	Epidemic, Upper Sind.

The epidemic figures for the talukas of Nawabshah district from 1901 to 1929 are given in Table II. It will be noticed that there were abnormally high figures in 1906, 1916, 1917 and 1929. Each of these epidemics, except that of 1916, had its centre in Upper Sind. It is evident that Nawabshah district, lying as it does on the border between Upper and Lower Sind, is affected to some extent by epidemics which have their centre in either area; but it is also clear that epidemic malaria in the district is never so severe as is the case in the extreme north of Sind, where epidemic figures of over 20 may be encountered. It is noteworthy that the northernmost taluka, Kandiaro, exhibits the highest epidemic figure in the case of each epidemic year. Here the land is high-lying, and 70 per cent of the cultivation is on lift irrigation; i.e., the conditions approach most nearly to those in the extreme north of Sind, where epidemic malaria is most severe.

As to the cause of epidemic malaria in Nawabshah district, rainfall was in excess in the years 1916, 1917 and 1929, whilst in 1906 it was very slight. The total river level as registered at Bukkur gauge from June to October 1906 was however higher than in any other year except 1903. On the other hand, there were years in which there was a high flood level, but no increase in the epidemic figure. There were also non-epidemic years (e g., 1913 and 1927) where the rainfall was in excess; but in these years the whole of the rain fell in July, and none was recorded in August and September. On the whole, it would appear that the most important factor in the production of epidemic malaria in the district is an excess of rainfall in August and September, or in both of these months, whilst rain falling in July only has little or no effect.

Results of the present survey.

Details regarding the spleen and blood examinations of children from two to twelve years of age carried out in the various villages visited are set out in Table III.

Table III.

Spleen and parasite indices, Nawabshah District.

Village.	Children examined.	Number with enlarged spleen.	Splenic index.	Blood slides examined.	Number found infected.	Parasite index.	Subsoil water level (feet).
Naushahro Taluka.							
Bhiria	110	48	44	..	..	..	20
Mithani and Abji ..	210	24	11	..	..	..	30
Total Naushahro Taluka.	320	72	22·5	..	..	..	..

TABLE III—*contd.*

Village.	Children examined.	Number with enlarged spleen.	Splenic index.	Blood slides examined.	Number found infected.	Parasite index.	Subsoil water level (feet).
MORO TALUKA.							
Sadhuja	85	66	78	48	24	50	42
Dehran	45	22	49	43	6	14	48
Isaq Chand ..	12	3	25	12	3	25	50
Moro	128	23	18	50	8	16	50
Daras	125	18	14	50	7	14	35
Shahpur	75	15	20	45	5	11	45
Daulatpur ..	176	26	15	50	9	18	20
TOTAL MORO TALUKA	646	173	26·8	298	62	20·8	..
SAKRAND TALUKA.							
Jhunjan	41	8	19	..	..	..	15
Kazi Ahmed ..	57	41	72	45	10	22	25
Mir Jeth and Mohamed	16	2	12	..	..	..	..
Shahani Jo Got ..	17	3	18	..	..	..	23
Rahun	44	6	14	..	..	..	22
Dehran, Kaki Chandia and Shakal Chandia.	87	19	22	..	..	..	18
Sukia Manahi ..	34	4	12	..	..	..	22
Miani	63	45	71	..	..	..	..
Sakrand	16	7	44	16	1	6	..
Kumblima ..	140	22	14	47	7	15	40
Mehrabpur ..	136	58	42	50	13	26	20
Mari	42	29	69	..	..	..	25
Dala Dehra ..	33	8	24	..	..	..	30
TOTAL SAKRAND TALUKA	726	252	34·7	158	31	19·6	..

TABLE III—*concld.*

Village.	Children examined.	Number with enlarged spleen.	Splenic index.	Blood slides examined.	Number found infected.	Parasite index.	Subsoil water level (feet).
NAWABSHAH TALUKA.							
Nawabshah ..	232	29	13	51	3	6	30
Fakirji Khuhi ..	15	1	7	..	..	..	30
Rai Bahadur Kowda Mal.	36	0	0	..	..	..	25
Haji Peria, Bida Khan Jamali and Imam Ali Shah.	32	0	0	..	..	..	25
TOTAL NAWABSHAH TALUKA.	315	30	9·5	51	3	5·9	..
SHAHDADPUR TALUKA.							
Sarhari	28	14	50	..	..	..	15
Nawazdhari ..	21	10	47	..	..	..	15
Faiz Mohd. Jo Got ..	19	0	0	..	..	..	12
Mohd. Kamal Kiria ..	19	2	10	..	..	..	12
Rangho Khan Talpur	68	7	10	20	3	15	35
Allah Ditta Khas Kheli	21	3	14	..	..	..	40
Karam Dad Katchi ..	31	1	3	..	..	..	42
Khoto Zardari, Koto Zakro and Manak Zardar.	25	4	16	..	..	..	40
TOTAL SHAHDADPUR TALUKA.	232	41	17·7	20	3	15	35
TOTAL NAWABSHAH DISTRICT.	2,239	568	25·4	437	99	22·7	..

1. *Naushahro Taluka.*

The old eastern course of the Indus is represented throughout the length of this taluka either by a deep continuous bed of sand, or by a well-defined low tract. The riverain border, as has been noted above, is covered with forests, which at times suffer from the encroachments of the river. In 1923 there were

2,300 wells in the taluka, of which 2,150 were used for irrigation purposes only. Approximately half the cultivation is on flow. The main summer crops are juari and bajri, and the main winter crop is wheat. A little cotton and rice are also grown.

Bhiria is a village with a population of about 2,100, situated 8 miles to the north of Naushahro town, the taluka headquarters, and 12 miles east of the Indus. It is built on an elevated site, but lies in what is really the old bed of the Indus previously alluded to. There are two canal distributaries running within 150 to 200 yards of the village, and a number of excavations in the immediate vicinity, which are filled with water from the distributaries during the inundation period. Water was present in two of these at the time of the present survey, and a few larvæ of *A. culicifacies* and *A. subpictus* were found in them. Beyond these excavations the village is surrounded by dry-crop cultivation. The subsoil water level was 20 to 25 feet. It is said that the surrounding country is liable to become flooded when the river level at Bukkur reaches 15 feet. As the result of 1½ hours' search for adult mosquitoes in the village, seven specimens of *A. culicifacies* and two of *A. subpictus* were caught. The splenic index was 44 (110 observations), and the apex-umbilicus measurement of the average enlarged spleen 6 8 cm.

Mithani and Abji, with a combined population of about 2,300, are two villages situated close to one another about 7 miles to the west of Naushahro, and 4 miles east of the Indus, in the midst of dry-crop cultivation. Mithani was built about 15 years ago, and is placed on an elevated site, with wide streets and good drainage. No borrow-pits or other suitable breeding-places were found in the immediate vicinity. The nearest canal distributary runs about 500 yards from the village. The splenic index for the two villages was 11 (210 observations), and the apex-umbilicus measurement of the average enlarged spleen was 9 4 cm. The subsoil water level was 30 feet. Prolonged search for adult mosquitoes resulted in the capture of a single specimen of *A. culicifacies* in Abji; none were found in Mithani.

2. *Moro Taluka.*

This taluka lies immediately to the south of Naushahro taluka, and is geographically similar to it. Its cultivation is half on lift and half on flow, and the staple crops are the same as in Naushahro. Jambho (oilseed) is also extensively grown.

Moro, the headquarters of the taluka, is situated about 8 miles to the east of the Indus, on the Rohri-Hyderabad trunk road, and has a population of about 1,600. There are canal distributaries on each side of the village at a distance of some 50 yards from it, and a number of excavations of various sizes surround it. One of these is about 100 yards long by 50 yards broad, and at the time of the survey this contained a little water, but no larvae were

found in it. Dr. R. V. Shiveshwarkar, formerly Assistant Director of Public Health, Sind Registration District, informed one of us that prior to 1924, when he visited Moro and found a splenic index of 45 among the school children, this excavation was filled with water from one of the canal distributaries. On his advice this practice was stopped, and to this he attributed the fact that malaria had decreased since that time. At the time of the present survey the splenic index was 18 (128 observations) and the parasite index 16 (50 observations). The apex-umbilicus measurement of the average enlarged spleen was 10 3 cm. The subsoil water level was 50 feet. Beyond the distributaries on each side of the town is dry-crop cultivation. Prolonged search for adult mosquitoes proved negative.

SADHUJA is a village with a population of about 600, situated 8 miles north of Moro, and 10 miles east of the Indus. It is said that the surrounding country is liable to be flooded when the river level at Bukkur exceeds 13 feet, and signs of recent flooding were apparent at the time of the survey. On either side of the village there are a number of excavations, which were dry at the time of the survey. About 20 yards to the north is a large village pond, communicating with a canal distributary. This contained a quantity of *Spirogyra* and other aquatic vegetation, and *A. culicifacies* larvae were present in large numbers. The village lies in the midst of dry-crop cultivation. The subsoil water level was 42 feet. The splenic index was 78 (85 observations) and the parasite index 50 (48 observations). The apex-umbilicus measurement of the average enlarged spleen was 8 8 cm.

DEHRAN is a village with a population of about 250, situated 6 miles north of Moro and 8 miles east of the Indus, in the midst of dry-crop cultivation. To the south of the village is a pond about 200 feet long, in which a few larvae of *A. culicifacies* were found. A canal distributary runs about 150 yards from the periphery of the village, and the subsoil water level was 48 feet. The splenic index was 49 (45 observations) and the parasite index 14 (43 observations). The apex-umbilicus measurement of the average enlarged spleen was 10 cm.

ISAQ CHAND is a hamlet two miles south of Moro, with a population of about 100, lying in the midst of dry-crop cultivation. A canal distributary runs within 200 yards of the village, and the subsoil water level was 50 feet. Neither larvae nor adult mosquitoes were found. The splenic index and parasite index were each 25 (12 observations).

DARAS is a village with a population of about 1,100, lying 3 miles north-east of Moro, and 8 miles east of the Indus. It is situated on slightly elevated ground, and is surrounded by dry-crop cultivation in its immediate neighbourhood, though there is a small amount of rice cultivation about 1½ miles from the village. A canal distributary runs about 2" yards from the periphery, and there is a pond close by about 100 feet in length. No larvae were found in

this, though it appeared to be a favourable breeding-place. The subsoil water level was 35 feet. The splenic index was 14 (125 observations) and the parasite index 14 (50 observations). The apex-umbilicus measurement of the average enlarged spleen was 9·6 cm.

SHAHPUR is a village with a population of about 500, situated 6 miles south of Moro and 4 miles east of the Indus. A canal distributary runs about 100 yards from the village, and there are a number of excavations, most of which were dry at the time of the survey. No larvae or adult mosquitoes were found. The subsoil water level was 45 feet. The splenic index was 20 (75 observations) and the parasite index 11 (45 observations). The apex-umbilicus measurement of the average enlarged spleen was 8·6 cm.

DAULATPUR is a village with a population of about 1,600, situated 12 miles south of Moro, and 4 miles east of the Indus. A canal distributary runs 60 yards from the village, and there are a number of borrow-pits in the immediate vicinity, all of which were dry at the time of the survey. A large excavation close to the edge of the village contained a little water, but no breeding was detected. The villagers stated that in the year 1924 the surrounding country was flooded. The subsoil water level was 20 feet. The splenic index was 15 (176 observations), and the parasite index 18 (50 observations). The apex-umbilicus measurement of the average enlarged spleen was 8 6 cm.

3. *Sakrand Taluka.*

This taluka has a very large area adjacent to the river under forest. There are more trees and jungle in it than in any other taluka of the division. The areas under lift and flow irrigation are approximately equal. In addition to the usual crops of the district, considerable areas are under rice and cotton.

JHUNJAN is a village with a population of about 400, lying 3 miles to the east of the Indus, and 17 miles west of Sakrand, the taluka headquarters. A canal distributary runs half a mile from the village, and there are numerous excavations in its immediate vicinity, which were dry at the time of the survey. On the west of the village there is dry-crop cultivation, on the east jungle, and on the south vegetable gardens. There is some rice cultivation about three-quarters of a mile from the village. The villagers stated that the surrounding country was extensively flooded in the year 1924, when a minor flowing 300 yards from the south of the village overtopped its banks. The subsoil water level was 15 feet. No anophelines were captured in the village. The splenic index was 20 (41 observations), and the apex-umbilicus measurement of the average enlarged spleen was 9·6 cm.

KAZI AHMED is a village with a population of about 450, lying 10 miles west of Sakrand, and 7 miles east of the Indus. There are two distributaries running about 200 yards from the periphery, and a number of excavations in

the immediate vicinity, most of which were dry at the time of the survey. Larvae of *A. culicifacies* were found in considerable numbers in two small excavations containing water about 25 yards from the edge of the village. Half the circumference of the village is ringed with vegetable gardens, and a 'dhoro' (channel) runs about 200 yards from it. It is stated that when the river level at Bukkur exceeds 15 feet all the country west of the village is flooded. The subsoil water level was 25 feet. Out of 32 anophelines caught in the village, 20 were *A. culicifacies*, and the remainder *A. subpictus*. The splenic index was 72 (57 observations), and the parasite index 22 (45 observations). The apex-umbilicus measurement of the average enlarged spleen was 8·2 cm.

MIR JATH and MOHAMED are two temporary villages near Kazi Ahmed, with a combined population of about 100, belonging to one of the wandering tribes of Sind. Out of 16 children examined, two showed splenic enlargement.

SHAHANI JO GOT is a village with a population of about 100, situated in the midst of thick forest, about 3 miles east of Kazi Ahmed, and 12 miles north of Sakrand. Two canal distributaries run about 200 yards from the village, and there are a number of borrow-pits and a village pond, which were however dry at the time of the survey. The subsoil water level was 23 feet. The splenic index was 18 (17 observations).

RAHUN is a village with a population of about 120, situated in the midst of dry-crop cultivation, two miles north of Kazi Ahmed, and 8 miles east of the Indus. A canal distributary runs within 100 yards of the village, and there are two excavations in the immediate vicinity, but these were dry at the time of the survey. The subsoil water level was 22 feet. The splenic index was 14 (44 observations).

DEHRAN, KAKI CHANDIA and SHAKAL CHANDIA are three villages close to one another, situated 6 miles west of Kazi Ahmed and 20 miles west of Sakrand, with a combined population of about 700. They lie in the midst of dry-crop cultivation, the subsoil water level being 15 to 20 feet. Dehran is liable to flooding when the river level at Bukkur exceeds 15 feet, and the other two villages when it exceeds 16 feet. A pond near Dehran was examined for larvae, but none were found. The splenic index for the three villages was 22 (87 observations), and the apex-umbilicus measurement of the average enlarged spleen was 9·0 cm.

SUKIO MANAHI is a village with a population of about 250, situated 7 miles east of Sakrand, and 14 miles from the river Indus, in the midst of dry-crop cultivation. A canal distributary runs within 200 yards from the village, and there are two small excavations in the immediate vicinity, but these were dry at the time of the survey. The subsoil wate level was 22 feet. The splenic index was 12 (34 observations).

MIANI is a temporary village with a population of about 400, belonging to one of the wandering tribes of Sind, and established 3 years ago. It lies on the bank of an irrigation tank, about 400 yards from the village of Sakrand. The tank, which irrigates the Government Agricultural Farm, is about 2 miles long and one mile broad. At the time of the survey larvae of *A. culicifacies* were found in large numbers along the edge of the tank, in which was a quantity of *Spirogyra* and other aquatic vegetation. The splenic index was 71 (63 observations), and the apex-umbilicus measurement of the average enlarged spleen 7·2 cm.

SAKRAND itself is a very small village situated about 400 yards from a channel which feeds the tank. Out of 16 children examined in the school, 7 (44 per cent) were found to have enlarged spleens.

KUMBLIMA is a village with a population of about 600, lying 8 miles east of Sakrand, and 16 miles east of the Indus. A canal distributary runs at a distance of 200 yards from the village, and beyond this there is dry-crop cultivation. There are a number of excavations within 100 yards of the village, which were dry at the time of the survey. The subsoil water level was 40 feet. The splenic index was 16 (140 observations), and the parasite index 15 (47 observations). The apex-umbilicus measurement of the average enlarged spleen was 9 3 cm.

MEHRABPUR is a village with a population of about 700, situated 7 miles west of Sakrand and 3 miles east of the Indus, in the midst of forest. Immediately behind the village there is a large brick-field with a number of excavations, some of which contained water. In two of these larvae of *A. culicifacies* were found. There were also a number of borrow-pits surrounding the village, but these were dry at the time of the survey. The villagers stated that the surrounding country is liable to extensive flooding whenever the river level at Bukkur exceeds 15 feet. The subsoil water level was 20 feet. The splenic index was 42 (136 observations), and the parasite index 26 (50 observations). The apex-umbilicus measurement of the average enlarged spleen was 7 4 cm.

MARI is a village with a population of about 1,000, situated 6 miles west of Sakrand and 4 miles east of the Indus, surrounded by dry-crop cultivation. It lies on the bank of a large irrigation tank, containing much aquatic vegetation. Large numbers of larvae of *A. culicifacies* and *A. subpictus* were found in this. The subsoil water level was 25 feet. The splenic index was 69 (42 observations), and the apex-umbilicus measurement of the average enlarged spleen was 8·6 cm.

DALA DEHRA is a village with a population of about 200, situated 3 miles north of Sakrand in the midst of dry-crop cultivation. A canal distributary runs within 400 yards of the village, and there are a number of excavations, which were dry at the time of the survey. The subsoil water level was 35 feet.

The splenic index was 24 (33 observations), and the apex-umbilicus measurement of the average enlarged spleen 9·2 cm.

4. *Nawabshah Taluka.*

This taluka, formerly known as Nasrat, consists of two distinct parts, which are divided by the Nasrat Canal. The eastern part is sandy desert, and was not visited during the present survey. The western portion is cultivated, about three-fourths of the cultivation being on flow. Bajri and cotton are the staple crops.

NAWABSHAH, the district and taluka headquarters, is a rural town, with a population of about 5,000, situated 24 miles east of the Indus. The south-western portion, known as Garibabad, has a number of canal distributaries and excavations in its immediate vicinity. Larvae of *A. subpictus* were found in certain cattle troughs, and in two water tanks in the railway yard. The subsoil water level was 32 feet. The splenic index was 13 (232 observations among school children), and the parasite index was 6 (51 observations). The apex-umbilicus measurement of the average enlarged spleen was 8 5 cm.

FAKIRJI KHUHI is a village with a population of about 200, situated 2½ miles north of Nawabshah, in the midst of dry-crop cultivation. There is no canal distributary within half a mile of the village, and no excavations or other possible breeding-places were seen. The subsoil water level was 30 feet. One child out of 15 examined was found to have an enlarged spleen.

RAI BAHADUR KOWDA MAL is a village with a population of about 300, situated 3 miles to the north of Nawabshah. There is no canal distributary within half a mile of the village. The subsoil water level was 25 feet. The splenic index was nil (36 observations).

BIDA KHAN JAMALI, HAJI PERIA JAMALI and IMAM ALI SHAH are three villages with a combined population of about 300, situated close together, 3 miles to the west of Nawabshah. No breeding-places were found in the vicinity at the time of the survey The subsoil water level was from 25 to 28 feet. The splenic index was nil (32 observations).

5. *Shahdadpur Taluka.*

The western border of the taluka is formed by the old bed of the Indus previously alluded to, a series of 'dhoros,' ravines, mounds and low sand hills running along it. The irrigated area lies high on the whole, and about two-thirds of it are cultivated on lift. Cotton and bajri are the chief crops, but some rice is grown in certain low-lying areas.

SARHARI is a village with a population of about 300, situated 15 miles north-west of Shahdadpur and 14 miles east of the Indus. About half of the circumference of the village is ringed with rice cultivation, and there are two

canal distributaries within 300 yards of its edge. There are a number of excavations in its immediate vicinity, in two of which larvae of *A. culicifacies* were found. The subsoil water level was 15 feet. The splenic index was 50 (28 observations), and the apex-umbilicus measurement of the average enlarged spleen was 8 0 cm.

NAWAZDHARI is a village with a population of 150, situated 19 miles north-west of Shahdadpur. There are a number of vegetable gardens round the village, and some rice is grown within about 400 yards of its periphery. A canal distributary runs close to the village, and there are a number of excavations, in some of which larvae of *A. culicifacies* were found. The subsoil water level was 15 feet. The splenic index was 48 (21 observations), and the apex-umbilicus measurement of the average enlarged spleen 9·2 cm.

FAIZ MOHAMED JO GOT is a village with a population of about 120, situated 19 miles north-west of Shahdadpur. It was built in 1922, on an elevated site, but there is rice cultivation within half a mile of its periphery. The nearest canal distributary is 400 yards from the village. No borrow-pits or other excavations were seen in the vicinity. The subsoil water level in a well near the rice area was 12 feet. The splenic index was nil (19 observations).

MOHAMED KAMIL KIRIA is a village with a population of about 150, situated 20 miles north-west of Shahdadpur. The conditions were similar to those in the last mentioned village. Out of 19 children examined, two showed splenic enlargement, but one of these was a new-comer.

RANGHO KHAN TALPUR is a village with a population of about 400, situated 10 miles north-west of Shahdadpur, in the midst of dry-crop cultivation. There are a number of excavations in the vicinity, but these were dry at the time of the survey. The subsoil water level was 35 feet. The splenic index was 10 (68 observations), and the parasite index 15 (20 observations).

ALLAH DITTA KHAS KHELI and GULAM KHAS KHELI are two villages with a combined population of about 200, situated 10 miles north-west of Shahdadpur, in the midst of thick forest. The subsoil water level was 40 feet. A canal distributary runs within 200 yards, and there are some small excavations in the vicinity, but these were dry at the time of the survey. The splenic index was 14 (21 observations).

KARAM DAD KATCHI, KHOTO ZARDARI, KHOTO ZAKRO and MANAK DADAR are near the last mentioned villages, and conditions in them are similar. Out of 56 children examined from these four villages, five were found with enlarged spleen (splenic index 9).

DISCUSSION ON THE RESULTS OF SPLEEN AND BLOOD EXAMINATIONS.

From the above account it may be concluded that the amount of endemic malaria existing in the tract under review taken as a whole is moderate in amount, as would be expected from the character of the country, which is

generally high-lying, and the type of cultivation, which consists chiefly of dry crops, more than half the irrigation being by lift.

There are, however, certain villages which show high splenic indices, depending on local conditions. Thus, those situated in the former bed of the Indus, where the surrounding country is liable to be flooded when the river level at Bukkur exceeds 15 feet, are highly malarious, e.g., Bhiria, Sadhuja, Dehran and Kazi Ahmed. Again, Miani and Mari, villages situated on the bank of large irrigation tanks with profuse breeding of *A. culicifacies* in them, are highly malarious. The villages visited in Nawabshah and Shahdadpur talukas, lying from 15 to 25 miles distant from the river, show very little malaria incidence, with the exception of Sarhari and Nawazdhari, which are situated in a tract more low-lying than the rest of the district, with some rice cultivation in their immediate vicinity.

It is interesting to compare the splenic index figures for four localities in the district which were visited by De Sousa (1914) with those found in the present survey (Table IV).

TABLE IV.

Village.	De Sousa, 1913.			Present Survey, 1928-29.		
	Number examined.	Number found with enlarged spleen.	Splenic index.	Number examined.	Number found with enlarged spleen.	Splenic index.
Sakrand and Miani	220	131	60	79	52	66
Kumblima ..	85	50	59	140	20	14
Mehrabpur ..	163	116	71	136	58	42
Mari	15	11	73	42	29	69

It will be seen that at Sakrand (with Miani) and Mari, which lie on the banks of large irrigation tanks, the figures are practically the same for both surveys. As stated above the high degree of malaria incidence in these villages is attributable to the profuse breeding of *A. culicifacies* in the irrigation tanks: and as this condition would be present from year to year, it is natural to expect that endemic malaria in these villages would be more or less static.

In Mehrabpur, De Sousa found an index of 71, as against 42 found in the present survey. There is probably here always a high degree of endemic malaria, but as this depends chiefly on the amount of flooding from the river from year to year, one would expect the incidence of malaria to vary considerably, and to be less static than in villages situated beside irrigation tanks.

In Kumblima, on the other hand, De Sousa's figures were 59, as against 14 in the present survey. This is a village built on elevated ground and surrounded by dry-crop cultivation, so that conditions are comparable to those in the dry-crop areas of Upper Sind, where spleen indices are normally low, but become very high during an epidemic, and remain high during the years immediately following it. It is possible that there had been a localized epidemic in this area within a year or so of De Sousa's investigation.

Anopheline mosquitoes of Nawabshah district.

The only two species of anopheline met with in the course of the present survey were *A. culicifacies* and *A. subpictus*. As in other parts of Sind, there is no doubt that *A. culicifacies* is the principal, if not the sole, malaria carrier. This species was found either in the larval or adult form in all the villages where the splenic index was high.

The probable effect of the barrage scheme on malaria in Nawabshah District.

Under the Barrage Scheme the district will receive perennial irrigation from the great new Rohri Canal, instead of inundation irrigation from canals coming off directly from the backwaters of the Indus. This will result in a very large increase in the cold weather cultivation, and should bring increased prosperity to the population. If the Barrage Scheme, as seems possible, should reduce the amount of flooding in the region of the old bed of the Indus, and in the tract immediately adjoining the present course of the river, the incidence of malaria should be lessened. If this does not occur, and if the effect of the Barrage Scheme is to raise the general level of the subsoil water to a considerable extent, some increase in the amount of endemic malaria may be expected.

Summary

(1) The survey, which was carried out in December 1928 and January 1929, was confined to the western portion of Nawabshah District, almost all the villages visited being within 20 miles of the river Indus.

(2) Endemic malaria in the district is on the whole moderate in amount, as would be expected from the character of the country, which is high-lying, and the type of cultivation, which consists chiefly of dry crops.

(3) Certain villages in the tract surveyed are however highly malarious, depending on local conditions, i.e., those lying in the former bed of the Indus and liable to flooding from the river, those situated on the banks of large irrigation tanks, and those in low-lying tracts where rice is grown.

(4) The district, lying as it does on the border between Upper and Lower Sind, reacts to some extent to epidemics of malaria having their centre in both

these areas. An excess of rainfall in August and September appears to be the most important factor in determining the incidence of epidemic malaria in the district.

(5) If the Barrage Scheme results in a reduction of flooding, the incidence of endemic malaria in the district will probably be lessened. If on the other hand it does not do this, but raises the general level of the subsoil water to a considerable extent, there will probably be some increase in endemic malaria.

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MALARIA IN SIND.

Part V.

MALARIA IN UMARKOT AND CHHACHHRO TALUKAS OF THAR AND PARKAR DISTRICT (LOWER SIND).

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INTRODUCTION.

Previous observations.

The only available record of any previous observations in the tract under review is the statement of Major W. O'S. Murphy, I.M.S., formerly Deputy Sanitary Commissioner of Sind, quoted by Young and Majid (1930), that 'in Thar desert, though the people are poor, the children are healthy, and splenic enlargement is rare.'

Period of present survey.

The investigations were carried out from January 12 to January 19, 1931.

Tract surveyed.

The localities visited were in the following talukas of Thar and Parkar District, Lower Sind (*see* Map, p. 509):—

Umarkot.
Chhachhro.

General character of tract.

Thar and Parkar District lies between 24° 13′ and 26° 21′ North Latitude and 63° 40′ and 71° 11′ East Longitude, and has an area of 13,638 square miles. It is bounded on the north by Khairpur State, on the east by the states of Jesalmer and Merwar, on the south by the Rann of Cutch, and on

the west by Nawabshah and Hyderabad districts. It is divided into two main portions which are absolutely distinct from one another, the irrigated area of the west, sometimes known as the Pat, and the desert area to the east, the Thar, which constitutes a portion of the vast tract of country which embraces the Rajputana states, and is often designated in maps as the Great Desert. The Eastern Nara is for a long distance the line of demarcation between the two regions, and further south, at Umarkot for example, the fusion of the two is clearly marked. It is possible to stand on the walls of the fort and in one direction to see sandhills continuing as far as the horizon, and in the other to see the rich alluvial plains of Sind, with vast stretches of rice cultivation, and roads lined everywhere with avenues of trees. The latter region is irrigated by the Jamrao and Mithrao canal systems, and yields abundant crops of rice, wheat and cotton. The desert area has for ages been a great depository of the finest sand, which is caught up by the fierce winds which blow from the sea during the hot season, and is swept away to the north-east. Long ridges are thus formed, parallel with the direction of the wind. The ridges are naturally irregular and only roughly parallel, so that they often enclose sheltered valleys, above which they rise to a height of some one hundred and fifty feet. These valleys are frequently moist enough to admit of cultivation, and when not cultivated they yield luxuriant crops of rank grass. By the inhabitants of the desert the fodder is considered particularly nutritious, and their opinion is supported by the large exports of *ghi* and fine cattle in good years. Even on the sandhills a very little rain suffices to sustain a surprising amount of vegetation, consisting of Salvadora (*Khabar*), stunted *Ber, Babul* trees and small shrubs of kinds which camels eat. But the extraordinary saltness of the subsoil, and the consequent difficulty of finding water fit to drink, renders many tracts quite uninhabitable.

Of the total area of the district, namely 13,636 square miles, 10,542 square miles are desert, comprising the whole of the Diplo, Chhachhro and Mithi talukas, nearly the whole of Nagar Parkar and Khipro, and part of Sanghar and Umarkot talukas. For revenue purposes, the district has been divided into three divisions, viz., Nara Valley division consisting of Umarkot, Pithoro, Sanghar and Khipro talukas; Mirpur Khas division, consisting of Mirpur Khas, Jamesabad and Digri talukas; and the Desert division, consisting of Nagar Parkar, Chhachhro, Mithi and Diplo talukas. Of these, malaria conditions in Mirpur Khas division have already been studied (Covell and Baily, 1930*b*). The present paper deals only with malaria conditions in Umarkot taluka (Nara Valley division) and Chhachhro taluka (Desert division).

Climate.

The climate differs considerably in the two portions of the district. In the Nara Valley it is temperate, as the climate of Sind goes, being neither

excessively hot in summer nor very cold in winter. In the desert area, however, the hot weather is very severe, a violent hot wind causing the whole atmosphere to be charged with dust and fine sand. The people who live in this desert describe this time of the year as almost intolerable; and indeed, with the fearful heat day and night, the sand in their mouths, eyes, food and clothing, the want of water and the almost sleepless nights, it must be as near a realization of the infernal regions as they can expect to find in this world (*Gazetteer of the Province of Sind,* 1926).

Rainfall.

The amount of annual rainfall is very variable, the average at Umarkot being 6 to 9 inches. In 1899, only 6 cents fell, whilst in 1913 there were 16·36 inches. Most of the rain falls in the months of July, August and September. The amount of rainfall recorded for these three months at Umarkot and Chhachhro during the period 1901 to 1930 is shown in Table I.

TABLE I.

Monsoon rainfall and epidemic figures for Umarkot and Chhachhro Talukas for the period 1898 *to* 1930.

Year.	RAINFALL FIGURES (INCHES).						EPIDEMIC FIGURES.		REMARKS.
	UMARKOT.			CHHACHHRO.			UMARKOT.	CHHACHHRO.	
	July.	Aug.	Sept.	July.	Aug.	Sept.			
1898	4·61	..	1·15	1·22	..	0·43	2·31	1·17	
1899	..	..	..	..	..	..	10·50	3·85	Famine.
1900	0·25	4·65	0·97	2·31	8·35	2·44	6·94	4·90	
1901	1·10	1·23	..	0·61	0·14	..	1 49	1·22	
1902	1·02	4·05	2·71	0·97	8·27	1·37	2·00	1·42	
1903	3·72	..	..	5·68	0·57	2 53	0·75	0·70	
1904	1·02	0·05	..	1·79	0·06	0·83	0·66	0·35	
1905	1·62	..	0·45	5·73	..	2·16	1·73	0·25	
1906	0·65	2·03	3·86	0·95	6·29	1·93	1·13	0·72	
1907	0·54	3·31	..	3·59	5·41	..	1·13	0·72	
1908	5·72	8·32	..	18·30	4·90	..	1·22	0·60	
1909	8·26	0·40	1·32	5·21	2·82	1·73	0·80	0·80	
1910	3·88	4·56	..	3·36	2·09	..	0·46	0·90	

TABLE I—*concld.*

Year.	RAINFALL FIGURES (INCHES).						EPIDEMIC FIGURES.		REMARKS.
	UMARKOT.			CHHACHHRO.			UMARKOT.	CHHACHHRO.	
	July.	Aug.	Sept.	July.	Aug.	Sept.			
1911	..	..	0·02	..	0·17	..	1·02	1·85	
1912	3·93	2·49	0·03	4·44	2·67	..	1·33	1·00	
1913	5·70	6·64	12·48	5·37	8·19	10·61	1·93	2·12	
1914	3·59	..	..	3·05	0·13	3·02	2·06	0·92	
1915	0·36	..	1·32	0·52	..	0·61	1·71	1·07	
1916	1·02	5·59	0·83	2·50	8·25	8·08	2·15	1·70	
1917	0·87	4·34	9·60	0·63	7·55	7·35	1·82	0·77	
1918	..	1·12	0·34	..	0·59	1·26	..	..	Influenza.
1919	13·17	0·92	..	7·54	3·36	..	..	..	
1920	0·50	1·29	..	1·63	2·35	..	0·46	0·15	
1921	7·35	3·90	1·82	13·69	0·60	4·20	1·08	1·10	
1922	2·42	1·22	1·16	1·64	2·62	3·53	0·31	0·72	
1923	2·79	3·03	..	0·55	3·10	..	0·55	0·75	
1924	5·83	4·83	1·29	7·61	4·66	3·04	1·40	1·55	
1925	0·22	0·26	..	0·50	1·70	..	1·26	1·07	
1926	2·40	6·15	1·49	2·25	7·91	5·52	1·24	2·02	
1927	15·51	3·28	..	13·44	4·85	0·31	1·69	2·07	
1928	1·83	1·88	0·22	3·30	1·65	0·18	0·60	0·77	
1929	14·50	9·47	..	13·20	8·39	..	1·26	1·47	
1930	2·57	1·18	0·52	2·32	0·30	0·32	..	..	

Epidemic malaria.

The epidemic figures for Umarkot and Chhachhro talukas for the years 1898 to 1929 are shown in Table I, along with the rainfall figures. The only years in which the figures were raised to a significant degree were 1899 and 1900. The former year was a year of terrible famine in the desert tract and in the areas to the east of Sind and there was a large influx of refugees into the irrigated tracts of Lower Sind. In 1900 there was an extensive malaria

epidemic in Lower Sind, which was fully discussed by Covell and Baily (1930*a*). The only other year in the period under review in which there was epidemic malaria in Lower Sind was 1916; but there is no indication from the figures that Umarkot and Chhachhro talukas were affected. There appears to be no connection between rainfall and epidemic malaria in the two talukas, for there is no evidence of any epidemic from 1901 to 1929, in spite of heavy rainfall in the years 1908, 1913, 1917, 1927 and 1929.

Results of the present survey.

Details as to the spleen and blood examinations carried out in the various villages visited will be found in Table II.

Table II.

Spleen and parasite indices, Umarkot and Chhachhro Talukas.

Village.	Number of children examined.	Number found with enlarged spleen.	Splenic index.	Number of blood films examined.	Number found infected.	Parasite index.	Subsoil water level. (feet).
			Umarkot taluka.				
Jahiro	39	7	18	..	..	..	30
Khejrari ..	33	2	6	..	..	..	34
Khararo and Mandhal	46	12	26	..	..	..	14-20
Umarkot ..	215	41	19	50	21	43	65
Chil	51	8	16	..	..	..	110
Nabisar ..	46	9	18	20	3	15	51
Total Umarkot Taluka.	430	79	18·4	70	24	34·3	..
			Chhachhro taluka.				
Chelhar ..	157	5	3	20	4	20	160
Chhachhro ..	170	2	1	40	4	10	130
Khesar	101	1	1	..	..	..	70
Total Chhachhro Taluka.	428	8	1·9	60	8	13·3	..

1. *Umarkot Taluka.*

Of the total area of 1,459 square miles, 1,018 are desert and 448 irrigated land. The irrigated portion is watered by the Thar canal, coming off from

the Eastern Nara, and rice is the main crop, 90 per cent of the cultivation being under flow. In the desert area, which is of course dependent entirely on monsoon rains for its cultivation, bajri is the chief crop, and some juari also is grown. The villages surveyed were along a line stretching south and a little west from Chhor, a station on the Jodhpur Railway, to Nabisar, passing through Umarkot town. The villages were thus on the border-line between the irrigated and non-irrigated areas of the taluka.

UMARKOT, the taluka headquarters, is a rural town with a population of about 4,200, built on a slightly elevated site. There are two canal distributaries running about 200 yards north of the town. About 300 yards to the west of the town are a number of vegetable gardens, and at a distance of about half a mile to the west there is rice cultivation. There is a large tank, about 100 yards in length, close to the periphery of the town, but this is now empty. Till two years ago this tank was used as an irrigation tank for the neighbouring vegetable gardens, but since then the canal distributary feeding it has been closed. It is said that the incidence of malaria has diminished since the tank has been empty. There are a number of excavations in close proximity to the town, but these were all dry at the time of the survey. The subsoil water level was 65 feet. The desert extends to the periphery of the town on its south-western side. The splenic index was 19 (215 observations), and the parasite index 42 (50 observations). The apex-umbilicus measurement of the average enlarged spleen was 6 6 cm.

JAHIRO is a village with a population of about 300, situated 10 miles south of Umarkot, on a mound about 60 feet in height. The cultivation is entirely dry-crop, and is limited to a valley on one side of the village. Between the cultivated area and the village is a 'terai' (depression between sandhills), about 100 yards in length, in which rain water is collected during the monsoon months The villagers stated that water remains stagnant in this until the end of October, after which wells sunk in its bed will act as a reserve supply of water until the next monsoon. The subsoil water level at the time of the survey was 30 feet In years of scarcity the inhabitants migrate in large numbers to the Nara Valley in search of pasture for their cattle, and for employment. No breeding places were found, and no adult mosquitoes were captured in the village The splenic index was 18 (39 observations), the apex of two out of the seven enlarged spleens observed being less than 7 cm. from the umbilicus.

KHEJRARI is a village with a population of about 400, situated 5 miles south of Umarkot on a mound some 70 feet in height. A minor of the Thar canal flows at a distance of 200 yards from its edge, and there is dry-crop cultivation within 400 yards of the village. On one side of the village is a 'terai.' No actual breeding places were seen, and no adult anophelines were

caught. The subsoil water level was 34 feet. The splenic index was 6 (33 observations).

KHARARO is a village with a population of about 1,000, situated on a mound about 60 feet high, 5 miles north-east of Umarkot. There is dry-crop cultivation within half a mile of the village, and rice is grown about 1½ miles from it. There is a 'terai' on one side of the village, and two small excavations in the immediate vicinity, but these were dry at the time of the survey. The subsoil water level was 14 feet. In times of scarcity the inhabitants migrate to the Nara Valley. The splenic index was 25 (40 observations).

MANDHAL is a hamlet with a population of about 50, situated on a mound some 30 feet in height, 8 miles north-east of Umarkot. The subsoil water level was 20 feet. No breeding places were seen and no adult anophelines were caught. Two out of 6 children examined were found to have splenic enlargement.

CHIL is a village with a population of about 400, situated on a mound about 30 feet high, 16 miles south-west of Umarkot. A minor of the Thar canal runs 2 miles west of the village and irrigates a portion of the village lands. A 'terai' lies nearby, and there are a few small excavations in the vicinity, which were dry at the time of the survey. The subsoil water level was 140 feet. The splenic index was 16 (51 observations).

NABISAR is a village with a population of about 900, situated on a mound 50 feet high, 22 miles south-west of Umarkot. Dry-crop cultivation extends to within quarter of a mile of the village on the north and west, whilst on the south and east there is desert. On one side of the village is a brickfield and a large excavation. This was dry at the time of the survey, but the villagers stated that it contains water each year till about the end of December. No other likely breeding areas were seen The subsoil water level was 51 feet. The splenic index was 18 (46 observations), and the parasite index 15 (20 observations).

2. *Chhachhro Taluka.*

The taluka is a desert of sandhills, in the valleys between which are cultivated bajri, sesame (oilseed), field vetch and mung (green gram). There is no irrigation, the cultivation being entirely dependent upon the monsoon rainfall, which is very variable.

CHHACHHRO, the taluka headquarters, is a small rural town with a population of about 3,000, built on a mound some 30 feet high, 54 miles south of Gadro station on the Jodhpur railway line. The subsoil water level was 130 feet. There is dry-crop cultivation in the valley around the town. No breeding places were seen, and no adult mosquitoes caught. The splenic index was 1·1 (170 observations), and of the two children found with enlarged spleens

one had recently arrived from Umarkot. The parasite index was 10 (40 observations).

Khesar is a group of three small villages with a combined population of about 300, situated on a mound 60 feet high, 30 miles south of Gadro railway station. There is dry-crop cultivation in the valleys surrounding the villages, and two 'terais' at a distance of some 600 yards. No actual breeding areas were found. The subsoil water level was 70 feet. The splenic index was 2 (101 observations).

Chelhar is a village with a population of about 1,200, situated on a mound 70 feet high, 24 miles west of Chhachhro, in the midst of dry-crop cultivation. There are about 30 wells in the village, but all were dry except two at the time of the survey. The subsoil water level was 160 feet. No actual breeding areas were seen, but one specimen of *A. stephensi* was caught in a building near a well. The splenic index was 3 (157 observations), but one of the five children with enlarged spleen was a new arrival from Jamesabad taluka, a malarious locality. The parasite index was 20 (20 observations).

Discussion on the results of the spleen and blood examinations.

Out of 430 children examined in the villages in Umarkot taluka lying along the border line between the irrigated area and the desert, 79 or 18 per cent were found with enlarged spleens, the highest index being 26 at Khararo and Mandhal. Endemic malaria may be said to be moderate in this area, and this is to be expected, since the villages are built on elevated sites and none of them have rice cultivation in the immediate vicinity.

Out of 428 children examined in the villages in Chhachhro taluka, in a desert tract without irrigation and dependent exclusively on rainfall for its cultivation, 8 or 2 per cent were found with enlarged spleens, and two of these were new-comers to the desert tract. Endemic malaria is therefore extremely slight in this area, and indeed might be thought to be non-existent, but for the fact that 8 out of 60 children examined were found to have parasites in their peripheral blood. The absence of suitable breeding grounds for the carrier species of anophelines, the great depth of the subsoil water, and the presumably low degree of the atmospheric humidity as compared with the irrigated areas of Sind, are all unfavourable to the incidence of malaria. It is indeed possible that such few cases of malaria that do occur may be acquired when some of the people migrate to irrigated areas in times of drought and scarcity.

Anopheline mosquitoes of Umarkot and Chhachhro talukas.

The survey was undertaken at an unfavourable time of the year for anophelines, and even in the most malarious parts of Sind they are scanty at this time. No larvæ or adults were found in the villages in Umarkot taluka, but it is reasonable to assume that the malaria present in that tract is carried

by *A. culicifacies,* just as it is in the more profusely irrigated areas further west.

As regards the desert area, it is impossible to say whether *A. culicifacies* is present or not. It seems unlikely, from the absence of suitable breeding places and from the exceedingly low amount of endemic malaria, that this species is present in any number. As has been mentioned above, it is even uncertain as to whether there is any transmission of malaria at all in the desert tract, but the capture of a solitary specimen of *A. stephensi* in Chelhar suggests that this species may be breeding in the wells, and may possibly play a part in transmission.

Probable effect of the Barrage Scheme on malaria in Umarkot and Chhachhro talukas.

Under the Barrage Scheme there will be a great increase in the amount of cold weather cultivation in the irrigated area of Umarkot, and should the subsoil water be raised to any considerable extent, some increase of endemic malaria may be expected.

The desert tract, in which Chhachhro taluka lies, does not come under the Barrage Scheme, and will therefore not be affected.

Summary.

(1) A malaria survey of certain villages in Umarkot and Chhachhro talukas was made in January 1931.

(2) A series of villages visited in Umarkot taluka, situated on the border line between the irrigated area and the desert tract, showed a moderate amount of endemic malaria.

(3) Villages visited in Chhachhro taluka, lying in the midst of the desert, showed a very slight incidence of malaria. It is possible that such malaria as exists may be due entirely to the migration of the inhabitants into the irrigated areas in times of drought.

(4) In the last 35 years epidemic malaria only occurred in the tract under review in 1899 and 1900, when there was a large influx of persons from adjacent territories into Lower Sind owing to famine. An excess of rainfall in the monsoon months has fallen in several years since that date, without causing any appreciable rise in the epidemic figures of the talukas.

(5) The probable effect of the Barrage Scheme on the villages visited in Umarkot taluka will be to cause some increase in the amount of endemic malaria, if the subsoil water is raised to a considerable degree. Chhachhro taluka lies outside the area to be commanded by the Barrage Scheme, and will therefore be unaffected.

(6) It is considered that *A. culicifacies* is probably the carrier of malaria in the villages visited in Umarkot taluka. It is probable that any transmission which may occur in the desert tract is due to the presence of *A. stephensi.*

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MALARIA IN SIND.

Part VI.

POST-EPIDEMIC CONDITIONS IN A RICE-GROWING AREA IN KAMBAR TALUKA, LARKANA DISTRICT.

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[May 29, 1931]

INTRODUCTION.

In Part III of this series (Covell and Baily, 1930) an account was given of malaria conditions in two villages situated in a rice-growing area near Larkana town. The present paper is a further study of malaria conditions in the rice tract. But whereas the observations alluded to above were made during the year preceding the epidemic of 1929, those which form the basis of the present paper were carried out in the year following the epidemic.

Previous observations.

There are no previous records available of observations in the villages visited in the present survey, but Young and Majid (1930) found splenic indices of 45 at Kambar and 77 at Bher (which lies at the edge of a large 'dhand,' or tank, five miles south-west of Kambar) in 1927. One of us (J. D. B.) found splenic indices of 36 at Kambar, 54 at Bher and 50 at Changro (two miles from Bher) in 1928. In November 1929, three months after the commencement of the epidemic, the splenic indices at Kambar and Bher were 82 and 84 respectively.

Period of present survey.

The investigations which form the subject of the present paper were carried out from December 16 to December 18, 1930.

Tract surveyed.

A group of six villages situated in Kambar taluka, Larkana District, lying some six miles south of Kambar, the taluka headquarters, and 14 miles south-west of Larkana town.

General character of tract.

Kambar taluka is one of the finest and most fertile in Sind, although to the west of the chief town, Kambar, there is an extensive plain of salt land as bad as any in the province. The tract in which the villages under review are situated contains some of the best rice lands in Sind. The water supply is entirely from the Ghar canal and its branches, and the cultivation is exclusively by flow. The land is lowlying, the subsoil water level varying from 3 to 8 feet during the inundation, and from 5 to 10 feet during the non-inundation season. As regards climate, rainfall, irrigation, method of rice cultivation and staple crops, conditions are similar to those in Larkana taluka, previously described (Covell and Baily, 1930).

Five of the six villages visited lie within a circle of about one mile in diameter, two of them, Pakho and Karam Bok, being situated on the bank of a branch of the Ghar canal, and the other three Chandia, Bhola and Naogot, at distances varying from 600 to 1,200 yards from it. The remaining village, Khairpur Juso, lies about two miles to the east of Pakho. All the villages are surrounded by rice cultivation, which extends almost up to the houses, and all have numerous excavations and borrow-pits in their immediate vicinity. During the inundation period, i.e., from July to September, the area immediately surrounding the villages is flooded with water drained off from the ricefields ('pancho water'), the villages themselves being situated on slightly elevated sites. From the middle of September, when the water begins to get less in amount, isolated pools are left behind, in which *A culicifacies* breeds in large numbers.

Population.

The combined population of the six villages is about 3,500. More than 80 per cent of these are Mohammedan cultivators; the remainder are made up of persons of the bania class (money-lenders) and of the wandering tribes of Sind. The nutrition of the population, both children and adults, appears to be good.

Epidemic malaria.

The malaria epidemics of Upper Sind have been fully discussed elsewhere (Young and Majid, 1930; Covell and Baily, 1930). As noted above, a wave of epidemic malaria spread over Upper Sind in the autumn of 1929.

Breeding-places of Anopheline mosquitoes.

Suitable breeding-places for Anophelines abound in the immediate proximity of the villages. These are the 'pancho' water drained from the ricefields, the village 'dhands' (ponds), small canal distributaries, borrow-pits, wells, and swampy areas covered with hoof-prints of cattle. The Health Officer of the District Local Board, Larkana, has been carrying out antilarval measures round the five first-mentioned villages since August 1930, and since the majority of the breeding areas had recently been treated with oil or paris green, very few larvae were seen at the time of the survey. The bed of the canal acts as a prolific source of breeding of *A. culicifacies* till the end of November, but this was dry at the time of the present visit.

Adult mosquitoes.

Altogether 225 anophelines were captured in the first five villages. These were *A. culicifacies* 61 per cent, *A. subpictus* 28 per cent, and *A. pulcherrimus* 11 per cent. The percentage of females to males in each case was 79, 86 and 97 respectively.

Dissections.

Out of 39 specimens of *A. culicifacies* dissected, 2 (5 per cent) were found with gut infections. No gland infections were found.

RESULTS OF SPLEEN AND BLOOD EXAMINATIONS.

These are set out in Table I. It will be seen that the splenic indices in the six villages all lay between 69 and 98, a state of affairs which would be expected in the year following an epidemic of malaria. The adult spleen rates were from 50 to 82 in the various villages, and the parasite indices (children) varied from 17 to 31.

Allowing for the error unavoidable in dealing with small numbers, there does not appear to be much difference between malaria conditions in the different villages as shown by these figures: but a study of the sizes of the enlarged spleens shows very considerable variation. This is brought out in Table II, in the last column of which is given the percentage of spleens with apex-umbilicus measurements of less than 7 cm. to the total number of enlarged spleens in each village. This figure varies from 76 in Karam Bok to 27 in Chandia, and suggests that there was some difference in pre-epidemic conditions in the different villages.

TABLE I.

Results of spleen and blood examinations.

Village.	SPLEEN EXAMINATIONS.								BLOOD EXAMINATIONS.				
	CHILDREN.				ADULTS.				CHILDREN.				
	Number examined.	Number with enlarged spleen.	Splenic index.	Average enlarged spleen *(A-U).	Number examined.	Number with enlarged spleen.	Splenic index.	Average enlarged spleen *(A-U).	Number examined.	Number with parasites.	Parasite index.	Total parasite count per c.mm.	Average parasite count per c.mm.
Khairpur Juso.	52	51	98	6·4	38	31	82	6·1	35	11	31	5,440	595
Karam Bok	26	25	96	5·9	23	14	61	5·0	18	3	17	940	313
Chandia..	45	41	91	8·6	48	28	58	7·0	23	7	29	4,730	676
Naogot ..	41	36	88	7·5	20	12	60	5·0	11	2	18	1,520	760
Bhola ..	42	32	76	7·7	18	9	50	6 8	13	3	23	1,000	333
Pakho ..	26	18	69	7·5	12	8	67	5·6	..	..	..	..	..
TOTAL	232	203	87·5	7·2	159	102	64·1	5·7	100	26	26	13,630	524

TABLE II

Splenic indices and sizes of spleen (children).

Village.	Number examined.	Number with enlarged spleen.	Splenic index.	Size of average enlarged spleen *(A-U)	Percentage of spleens of less than 7 cm. A–U measurement.*
Karam Bok ..	26	25	96	5·9	76
Khairpur Juso ..	52	51	98	6·4	64
Pakho	26	18	69	7·5	50
Naogot	41	36	88	7·5	47
Bhola	42	32	76	7·7	31
Chandia	45	41	91	8·6	27

* The apex-umbilicus (A-U) measurement is given in centimetres, and the figure of course becomes smaller as the spleen becomes larger.

Observations carried out in the course of the inquiry have shown that in the rice-growing areas of Sind splenic indices are of the order of about 40 to 70 in inter-epidemic periods, the differences depending chiefly on the number and character of the breeding-places in the immediate neighbourhood. Thus, villages situated on the banks of the Ghar canal and its branches, or on the edge of extensive 'dhands' or tanks, invariably show very high splenic indices, whilst those situated at a distance from such breeding-places, though still highly malarious, show considerably lower indices.

In the present instance, the villages of Karam Bok and Pakho lie close to the canal, and Khairpur Juso is surrounded by breeding-places in which numerous larvae of *A. culicifacies* were found at the time of the survey. Naogot, Bhola and Chandia, on the other hand, are situated on more elevated sites than are the other three villages, and lie at a considerable distance from the canal. Though there are numerous breeding-places in the vicinity, they are not so near nor so eminently suitable for the breeding of *A. culicifacies* as in the former case.

It is always dangerous to argue from a small number of figures, but it seems reasonable that the explanation of the variations in the sizes of spleen in the different villages is that the amount of endemic malaria existing in them before the epidemic varied considerably. During the epidemic a large number of infections would be broadcast in all the villages. In the case of those which

TABLE III.

Age incidence of enlarged spleens (children).

Age group (years).	Number examined.	Number with enlarged spleen.	Percentage with enlarged spleen.	Size of average enlarged spleen *(A-U)
1–2 ..	5	3	60·0	12·0
3–4 ..	17	13	76·5	8·7
5–6 .	84	74	89·3	7·6
7–8 ..	74	67	90·5	7·5
9–10 .	52	46	88·5	6·3

* The apex-umbilicus (A-U) measurement is given in centimetres, and the figure of course becomes smaller as the spleen becomes larger.

showed comparatively few and small enlarged spleens in the inter-epidemic period, one would expect to find a large number of small enlargements after the epidemic; whilst in villages where there were already a large number of greatly enlarged spleens due to repeated infections over a long period, there

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MALARIA IN SIND.

Part VII.

MALARIA IN THE UPPER SIND FRONTIER DISTRICT.

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[June 30, 1931.]

INTRODUCTION.

Period of survey.

The investigations which form the basis of the present paper were made during four visits to the district, two of which took place in 1928, and the other two in 1930. A severe outbreak of malaria in epidemic form took place throughout Upper Sind in the autumn of 1929, so that the first two visits were made in the pre-epidemic, and the last two in the post-epidemic period (Table I). The first survey (January 1928) was carried out by Young and Majid (1930).

TABLE I.

Period of the surveys, and talukas visited.

	Talukas visited.	Period of surveys.
	Pre-epidemic period.	
1st survey ..	Kashmor, Kandhkot, Thul, Jacobabad	January 9 to 16, 1928.
2nd survey ..	Kandhkot	November 2 to 4, 1928.
	Post-epidemic period.	
3rd survey ..	Kashmor, Kandhkot, Thul, Jacobabad	September 22 to October 2, 1930.
4th survey ..	Shahdadkot	November 22 to 26, 1930.

TABLE II—*concld.*

Year.	January.		May.		July.		November.	
	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.
1902 ..	88	32	122	69	121	83	97	49
1903 ..	76	32	120	66	118	77	98	42
1904 ..	85	34	123	71	117	80	102	49
1905 ..	77	25	124	68	122	79	101	49
1906 ..	78·0	32·0	123·0	73·0	114·0	83·0	96·0	50·4
1907 ..	90·5	36·4	118·6	60·4	115·6	77·6	95·0	43·5
1908 ..	82·8	36·4	117·0	67·4	113·5	77·6	94·0	43·8
1909 ..	76·0	31·4	116·4	63·4	114 3	79·5	102·8	46·0
1910 ..	80·4	33·5	125·2	72·0	114·4	77·0	96·0	43·0
1911 ..	80·2	35·8	121·2	69·0	117·0	77·8	95·0	39·4
1912 ..	80·0	39·0	126·1	68·4	119·4	82·0	98·4	39·4
1913 ..	92·2	26·2	124·0	68·2	113·4	80·0	95·8	43·2
1914 ..	85·2	40·2	126·0	66·4	114·0	77·4	92·4	52·0
1915 ..	83·0	37·0	123·0	76·0	125·0	81·0	99·0	43·4
1916 ..	83·1	38·8	120·5	62·2	115·0	83·8	94·0	38·6
1917 ..	78·6	40·0	113·4	67 0	118·4	75·6	91·6	41·0
1918 ..	76·8	30·8	123·2	74·2	119·6	78·8	96·4	45·2
1919 ..	77·0	34·0	120·4	75·4	122·0	77·2	95·6	43·2
1920 ..	78·0	39·2	115·6	64·6	115·8	76·4	95·6	43·8
1921 ..	77·0	33·6	117·6	69·0	111·4	80·4	91·0	49·2

Climate.

Jacobabad is the hottest place in India at which there is a meteorological station, there being very few years in which the thermometer has not reached 120°F. in the shade. The average monthly maximum and minimum temperatures recorded for the months of January, May, July and November for the years 1896 to 1921 are given in Table II. The heat is usually fiercest in the second half of May and in June, though in May there may be a difference of some 50 degrees between the maximum and minimum temperatures. In June

TABLE III.

Monsoon rainfall figures recorded at the headquarters of the five talukas of the Upper Sind Frontier district.
1901 *to* 1930

Year.	KASHMOR.			KANDHKOT.			THUL.			JACOBABAD.			SHAHDADKOT.			REMARKS.
	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	
1901 ..	0·31	0·46	..	..	..	..	0·10	..	.	0·10	..	..	0·95	..	..	
1902 ..	..	0·47	..	..	..	..	..	0·69	0·35	..	0·69	0·35	..	0·44	0·59	
1903 ..	3·97	..	..	3·55	..	..	2·40	..	..	2·40	..	..	4·25	..	..	
1904 ..	..	..	..	0·14	..	..	..	..	..	..	..	..	..	..	..	
1905 ..	..	..	0·10	.	..	0·09	..	..	..	..	..	..	..	..	..	
1906 ..	..	2·31	..	..	1·17	1·10	..	3·88	..	..	3·88	..	..	1·37	0·35	Epidemic year.
1907	..	1·62	..	..	1·88	..	..	0·87	..	..	0·87	..	0·20	2·47	..	
1908 ..	1·30	0·31	2·20	3·22	1·90	0·07	0·98	0·56	..	0·98	0·56	..	1·62	0·20	..	
1909 ..	2·30	..	..	2·07	..	0·34	0·33	..	0·03	0·33	..	0·03	1·09	..	..	
1910 ..	0·35	1·00	..	1·60	..	..	1·61	0·36	..	1·61	0·36	..	4·16	..	..	
1911 ..	..	..	0·04	..	..	..	..	0·03	..	..	0·03	..	..	..	..	
1912 ..	0·13	..	..	1·13	0·56	..	0·15	..	..	0·15	..	..	0·86	0·41	..	
1913 ..	0·38	0·89	..	0·62	4·11	..	2·00	1·76	..	2·00	1·76	..	3·33	0·47	..	
1914 ..	7·09	0·65	..	1·20	..	0·07	3·36	..	..	3·36	..	..	4·12	..	0·08	
1915 ..	..	..	..	..	..	..	..	..	..	..	..	..	0·31	..	..	

TABLE III—*concld.*

Year.	Kashmor.			Kandhkot.			Thul.			Jacobabad.			Shahdadkot.			Remarks.
	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	July.	Aug.	Sept.	
1916 ..	..	1·33	..	..	0·78	..	..	1·80	..	..	1·80	..	..	7·78	..	
1917 ..	1·21	6·30	4·96	0·29	3·97	2·92	0·20	3·31	5·89	0·20	3·31	5·89	..	7·74	6·22	Epidemic year.
1918 ..	1·04	..	..	0·86	0·50	..	..	..	..	..	..	.	..	..	3·58	
1919 ..	0·50	0·22	..	1·88	0·22	.	0·81	0·73	..	0·81	0·73	..	0·92	..	..	
1920 ..	0·21	..	..	..	..	..	0·52	..	..	0·52	..	..	0·34	..	..	
1921 ..	5·80	0·67	..	0·61	0·85	..	0·23	0·77	..	0·23	0·77	..	0·85	2·95	0·48	
1922 ..	0·45	..	0·21	..	..	0·44	..	0·66	0·01	..	0·66	0·01	..	..	..	
1923 ..	..	2·42	..	0·12	2·70	..	0·07	3·31	..	0·07	3·31	..	..	..	..	
1924 ..	0·60	0·14	1·04	0·50	..	0·10	..	..	0·14	..	..	0·14	0·30	..	3·23	
1925 ..	6·52	1·50	..	4·34	2·35	..	1·95	1·47	..	1·91	1·96	..	0·36	0·15	..	
1926 .	0·10	2·18	..	0·44	5·83	..	1·50	4·70	0·40	0·93	1·9	0·6	0·41	0·48	3·7	
1927 ..	0·12	..	0·19	0·3	..	..	0·5	0·9	..	0·41	..	..	0·16	0·36	..	
1928 ..	0·12	0·30	..	..	0·26	..	2·95	..	..	0·40	..	..	0·13	0·10	..	
1929 ..	7·89	14·6	..	3·45	14·20	..	3·3	6·48	..	3·87	1·56	..	6·14	0·85	..	Epidemic year.
1930 ..	1·24	..	..	0·71	..	..	1·21	..	..	2·36	..	..	1·84	..	..	

the thermometer at times does not go below 90°F. for many successive days. In July the atmospheric humidity rises, and may stand between 60 and 85 per cent till October. From the second week in October the temperature rapidly falls, and fine bracing weather may be experienced up to March. The heat in the eastern part of the district is not so fierce as that of Jacobabad, owing to the proximity of the Indus.

Rainfall.

The rainfall figures registered at the headquarters of the five talukas of the district in the months of July, August and September for the years 1901 to 1930 are given in Table III. It will be seen that the figures of individual talukas show considerable variation. The highest figures were recorded in the years 1917 and 1929, which were years in which epidemic malaria visited the district. The bulk of the rainfall is precipitated in January, July and August, the average being about 4 inches per annum.

Cultivation.

In Shahdadkot taluka 73 per cent of the cultivation is under flow and the remainder under lift. In the other four talukas the percentage under flow varies from 91 to 97. The chief hot weather crops are juari, bajri and rice. Juari is the staple food of the district and is largely grown in all talukas. Bajri is the next most important crop, and is chiefly grown in Kandhkot, Thul and Jacobabad talukas. Rice is principally grown in Jacobabad taluka, and according to the *Gazetteer* the area under it is steadily increasing. The principal cold weather crops are wheat, rape and jambho, chickling vetch and gram.

Population.

About 80 per cent of the population are Mohammedans, of whom some 33 per cent are Baluchis. The general nutrition of the inhabitants is on the whole remarkably good.

TABLE IV.

Taluka epidemic figures for the Upper Sind Frontier District, 1901–1929.

Year.	Kashmor.	Kandhkot.	Thul.	Jacobabad.	Shahdadkot.	REMARKS.
1901 ..	1·80	2·36	2·04	2·14	3·22	
1902 ..	1·19	2·76	2·36	3·05	3·53	
1903 ..	2·26	2·04	1·34	3·17	1·61	
1904 ..	1·29	2·84	2·02	1·79	1·58	
1905 ..	1·92	3·08	3·50	3·71	2·55	

TABLE IV—*concld.*

Year.	Kashmor.	Kandhkot.	Thul.	Jacobabad.	Shahdadkot.	REMARKS.
1906 ..	6·15	6·00	5·03	4·17	3·85	Epidemic year.
1907 ..	1·62	2·40	2·86	2·83	1·80	
1908 ..	4·49	6·25	2·52	2·35	1·67	
1909 ..	1·32	2·16	1·63	1·68	1·67	
1910 ..	1·19	2·12	1·75	1·43	2·27	
1911 ..	1·19	0·13	0·49	1·08	0·89	
1912 ..	2·00	2·12	1·48	1·27	1·67	
1913 ..	1·73	3·72	3·05	4·80	3·08	
1914 ..	2·25	4·28	2·27	2·91	2·55	
1915 ..	1·32	2·48	2·34	2·54	1·57	
1916 ..	1·97	5·85	2·95	4·92	2·33	
1917 ..	12·28	27·05	13·15	13·11	8·55	Epidemic year.
1918 ..	..	..	..	.	..	
1919 ..	..	..	..	..	..	
1920 ..	0·67	2·68	0·23	1·54	1·22	
1921 ..	1·08	2·96	1·43	1·21	0·97	
1922 ..	0·98	2·08	1·75	1·62	1·22	
1923 ..	1·19	4·64	3·22	1·73	1·05	
1924 ..	2·43	2·64	1·75	2·16	1·32	
1925 ..	1·27	3·00	1·25	1·27	1·19	
1926 ..	1·38	3·28	0·68	1·66	1·25	
1927 ..	0·70	3·28	2·74	2·06	1·89	
1928 ..	0·94	1·50	1·70	2·24	2·20	
1929 ..	6·17	8·70	9·50	15·2	2·86	Epidemic ye

Epidemic malaria.

The epidemic figures of the different talukas of the district from 1901 to 1929 are given in Table IV. It will be seen that in this period there were three epidemic years, viz., 1906, 1917 and 1929.

The first two epidemics were discussed in detail by Young and Majid (1930). In 1906 the rainfall figures recorded in August in Thul and Jacobabad

were comparatively high (3 88 inches in each case), but there was but little rainfall in the other talukas of the district. It was however a year of high river levels. In 1917 the river levels were only moderately high, but rainfall was in excess throughout the district.

In 1929 there was heavy rainfall in July and August, the combined figures for the two months being 22 49 inches in Kashmor, 17 65 inches in Kandhkot, 9 78 inches in Thul, 5 43 inches in Jacobabad, and 6 99 inches in Shahdadkot. The river levels were also abnormally high, the readings at Bukkur gauge during the months of August and September being constantly over 14 feet for 35 days, over 15 feet for 32 days, over 16 feet for 17 days, and over 17 feet for 4 days (Table V). The epidemic figures were 6 17 in Kashmor, 8 70 in Kandhkot, 9 50 in Thul, 15 2 in Jacobabad, and 2 86 in Shahdadkot.

TABLE V.

River levels of the Indus recorded at Bukkur Gauge for the months of June to October 1929.

Dates.	1929.				
	June (feet).	July (feet).	August (feet).	September (feet).	October (feet).
1 ..	5·5	8·9	15·3	16·0	6·3
2 ..	5·7	8·4	15·4	16·3	6·1
3 ..	5·9	8·1	15·4	16·4	5·9
4 ..	5·9	8·0	15·5	16·9	5·7
5 ..	5·8	7·8	15·6	17·2	5·5
6 ..	6·4	7·8	15·8	17·4	5·4
7 ..	8·2	7·7	15·9	17·4	5·4
8 ..	8·8	7·8	16·1	17·3	5·3
9 ..	9·0	8·0	16·3	16·3	5·4
10 ..	9·9	8·3	16·7	15·2	5·4
11 ..	9·7	8·5	16·7	13·1	5·2
12 ..	9·8	8·5	16·7	11·1	5·1
13 ..	9·9	8·4	16·5	10·5	5·0
14 ..	10·2	8·3	16·0	9·9	4·8
15 ..	10·8	8·5	15·2	9·5	4·6

TABLE V—*concld.*

Dates.	1929.				
	June (feet).	July (feet).	August (feet).	September (feet).	October (feet).
16 ..	11·0	8·0	14·3	9·0	4·4
17 ..	11·1	8·2	13·8	8·9	4·2
18 ..	11·9	8·6	13·4	8·5	4·1
19 ..	10·5	9·1	13·1	8·3	4·0
20 ..	9·9	9·4	13·2	7·9	3·8
21 .	8·8	9·8	13·4	7·7	3·8
22 ..	8·7	11·0	13·9	7·6	3·8
23 ..	8·7	12·1	14·4	7·4	3·7
24 ..	8·5	12·5	14·9	7·3	3·5
25 ..	8·6	13·1	15·1	7·2	3·3
26 ..	8·7	13·1	15·5	7·1	3·2
27 ..	9·1	13·3	15·5	7·0	3·0
28 ..	9·4	14·0	15·3	6·9	3·0
29 ..	9·3	14·0	15·7	6·8	2·9
30 ..	9·2	14·8	15·7	6·6	2·7
31 ..	..	15·1	16·1	..	2·6

The figure for Jacobabad is extremely high, especially in view of the fact that the rainfall recorded at the taluka headquarters was less than that recorded in any other taluka of the district. A possible explanation is that Jacobabad is the most low-lying taluka of the district, as shown by the fact that more rice is grown there than in any other taluka. The natural drainage of the country being from east to west, the great excess of rainfall in the most easterly talukas would naturally result in a large amount of water drainage into Jacobabad taluka, rendering atmospheric conditions exceptionally favourable for the transmission of malaria, and providing innumerable breeding-places suitable for *A. culicifacies*. The high level of the Indus would also result in a greatly increased amount of water reaching this area by way of the inundation canals.

RESULTS OF THE SURVEYS.

Details as to the spleen examinations carried out in the various villages visited will be found in Table VI.

TABLE VI.
Results of spleen examinations.

Village.	Pre-epidemic period. Date of survey.	Number examined.	Number with enlarged spleen.	Splenic index.	A-U measurement of average enlarged spleen (cm.).	Post-epidemic period. Date of survey.	Number examined.	Number with enlarged spleen.	Splenic index.	A-U measurement of average enlarged spleen (cm.)
					KASHMOR TALUKA.					
Kashmor ..	i. 28	62	7	11·2	..	x. 30	111	91	82·0	8·2
Gulam Mohd. ..	i. 28	35	4	11·4	..	x. 30	30	22	73·3	8·0
Dakhan ..	..	..	..	..	..	x. 30	30	25	83·4	7·9
Qadar Buksh ..	..	..	..	..	..	x. 30	7	7	100·0	7·6
Dasti and Atta Mohd. Khan.	..	..	..	..	..	x. 30	20	15	75·0	8·5
TOTAL KASHMOR TALUKA.	i. 28	97	11	11·3	..	x. 30	198	160	81·0	8·0
					KANDHKOT TALUKA.					
Kandhkot ..	i. 28 xi. 28	92 204	24 20	28·0 10·0	.. 8·8	ix. 30	201	169	84·0	7·6
Haybat ..	i. 28 xi. 28	39 70	8 4	26·5 5·7	.. 8·5	ix. 30	58	51	88·0	6·9
Dari	xi. 28	110	23	20·9	8·8	ix. 30	100	92	92·0	6·3
Ghauspur ..	xi. 28	178	112	62·9	7·8	ix. 30	120	110	91·7	7·7
TOTAL KANDHKOT TALUKA.	i. 28 xi. 28	131 562	32 159	24·4 28·3	.. 8·5	ix. 30	479	422	88·1	7·1
					THUL TALUKA.					
Chana	..	..	..	..	..	ix. 30	121	113	92·6	7·2
Mirpur.. ..	..	..	..	..	..	ix. 30	123	106	86·2	7·7
Mir Hasan ..	i. 28	27	9	33·0	..	ix. 30	53	44	83·0	9·3
Garhi Hasan ..	..	..	..	..	..	ix. 30	57	49	86·0	8·8
Thul	i. 28	66	16	24·0	..	ix. 30	181	158	87·3	7·9
TOTAL THUL TALUKA	i. 28	93	25	26·9	..	ix. 30	535	470	87·8	7·7

TABLE VI—*contd.*

Village.	Pre-epidemic period. Date of survey.	Number examined.	Number with enlarged spleen.	Splenic index.	A-U measurement of average enlarged spleen (cm.).	Post-epidemic period. Date of survey.	Number examined.	Number with enlarged spleen.	Splenic index.	A-U measurement of average enlarged spleen (cm.).
					JACOBABAD TALUKA.					
Jacobabad ..	i. 28	100	17	17·0	..	x. 30	347	224	64·6	8·6
Jatohi ..	i. 28	25	8	32·0	..	x. 30	55	49	89·0	7·7
Sadik Bangar ..	..	..	..	..	..	x. 30	17	13	76·5	7·2
Dil Murad Khoso ..	..	..	..	..	..	x. 30	77	63	81·8	8·7
Bhalaidana Abad ..	..	..	..	..	..	x. 30	92	72	79·3	7·5
Ramzanpur ..	..	..	..	..	..	x. 30	37	23	62·2	9·2
Maulabad ..	..	..	..	..	..	x. 30	60	42	70·0	8·1
TOTAL JACOBABAD TALUKA.	i. 28	125	25	20·0	..	x. 30	685	486	71·0	8·2
					SHAHDADKOT TALUKA.					
Sando	..	..	..	..	..	x. 30	30	28	93·3	8·0
Changal.. ..	..	..	..	..	..	x. 30	25	20	80·0	9·4
Kot Ali Nawaz ..	..	..	..	..	..	x. 30	22	16	73·6	10·2
Aitbar Khan Chandia	..	..	..	..	..	x. 30	30	27	90·0	6·4
Got Daryakhan ..	..	..	..	..	..	x. 30	20	14	70·0	10·3
Sobdar Mastoi ..	..	..	..	..	..	x. 30	20	15	75·0	8·5
Chakiani ..	..	..	..	..	..	x. 30	40	35	87·5	9·3
Silra	..	..	..	..	..	x. 30	35	28	80·0	9·3
Shahdadkot ..	..	..	..	..	..	x. 30	365	296	81·3	9·1
Khan Mohd. Jamali	..	..	..	..	..	x. 30	31	25	80·0	10·1
Imam Buksh ..	..	..	..	..	..	x. 30	25	19	76·0	9·1
Khuda Buksh Jamali	..	..	..	..	..	x. 30	23	17	74·0	10·6

TABLE VI—*concld.*

Village.	Pre-epidemic period. Date of survey.	Number examined.	Number with enlarged spleen.	Splenic index.	A-U measurement of average enlarged spleen (cm.).	Post-epidemic period. Date of survey.	Number examined.	Number with enlarged spleen.	Splenic index.	A-U measurement of average enlarged spleen (cm.).
					SHAHDADKOT TALUKA—*concld.*					
Habibullah Khan ..	..	..	..	..		x. 30	34	26	76·2	10·6
Kamal Bhati ..	..	..	..	..		x. 30	15	13	86·7	8·8
Jiand Jarwar ..	..	..	..	..		x. 30	45	35	77·0	9·7
Metha Jamali ..	..	..	..	..		x. 30	10	7	70·0	10·2
Shahpur ..	..	..	.	..		x. 30	30	27	90·0	9·8
TOTAL SHAHDADKOT TALUKA.	..	..	..	..		x. 30	800	648	81·0	9·2
TOTAL UPPER SIND FRONTIER DISTRICT.	i. 28 xi. 28	446 562	93 159	20·8 28·3	 8·5	x. 30	2,647	2,186	81·0	8·2

1. *Kashmor Taluka.*

This is the extreme eastern taluka of the district, and has an area of 531 square miles, with a population of 36,000 (in 1921). The Kashmor bund practically divides the taluka into two halves, the land between the bund and the river being subject to annual floods. The soil of this area is highly fertile, and yields excellent cold weather crops.

KASHMOR, the taluka headquarters, has a population of about 1,000, and is situated on the banks of the Raj Wah (canal), four miles west of the Indus. The Kashmor bund runs from north to south close to one side of the town, which is further protected by two smaller bunds. The surrounding cultivation is dry-crop. Two canal distributaries run within 400 yards of the town, and the subsoil water level (October 1930) was 19 feet. A number of excavations surrounding the town contained water, and in three of these larvae of *A. culicifacies* were found. Of 25 adult anophelines caught in the town, 10 were of this species, and the remainder *A. subpictus*.

First survey (pre-epidemic).—In January 1928 the splenic index was 11·2 (62 observations).

Second survey (post-epidemic).—In October 1930 the splenic index was 82 (111 observations). the apex-umbilicus measurement of the average enlarged spleen being 8 2 cm. The parasite index (40 observations) was 50.

GULAM MOHAMED or PANDI KALWAR is a village with a population of 160 situated one mile south of Kashmor in the midst of thick forest, almost on the bank of the Kandhkot Raj Wah (canal). The area is liable to annual inundation from the Indus. Dry-crop cultivation extends to within 50 yards of the periphery of the village, and the subsoil water level (October 1930) was 16 feet. Larvae of *A. culicifacies* were found in two borrow-pits near the edge of the village.

First survey (pre-epidemic).—In January 1928 the splenic index was 11·4 (35 observations).

Second survey (post-epidemic).—In October 1930 the splenic index was 73·3 (30 observations), the apex-umbilicus measurement of the average enlarged spleen being 8·0 cm.

QADAR BUKSH is a village with a population of about 60, situated in the midst of dry-crop cultivation two miles south-east of Kashmor, between the bund and the river. Its cultivation is entirely dependent on the yearly inundations from the river. The subsoil water level (October 1930) was 16 feet.

No visit was paid to this village before the epidemic. In October 1930 seven children were examined, all of whom had enlarged spleens, the average apex-umbilicus measurement being 7 6 cm.

DAKHAN is a village with a population of about 100, situated in the midst of dry-crop cultivation, 10 miles west of Kashmor. A branch of the Raj Wah canal flows one mile to the north of the village and two distributaries from it run within 400 yards from its periphery. Some small excavations near the edge of the village contained water, but no larvae were found. In the village itself 19 adult anophelines were caught, of which 9 were *A. culicifacies*, and the remainder *A. subpictus*. The subsoil water level (October 1930) was 16 feet.

This village was not visited in the pre-epidemic period. In October 1930 the splenic index was 83 4 (30 observations), the apex-umbilicus measurement of the average enlarged spleen being 7 9 cm. The parasite index was 40 (10 observations).

DASTI and ATTA MOHAMED KHAN are two small temporary villages situated in the midst of dry-crop cultivation ten miles west of Kashmor. No visit was paid to these villages before the epidemic. In October 1930 the splenic index was 75 (20 observations), the apex-umbilicus measurement of the average enlarged spleen being 8·5 cm.

2. *Kandhkot Taluka.*

This taluka lies immediately to the west of Kashmor, and has an area of 536 square miles, with a population of 53,134 (in 1921). The whole area

is a flat plain, and used to suffer from floods caused by torrents from the Bugti Hills, which lie some 16 miles beyond its northern border. These have now been checked by the construction of the Frontier Raj Wah.

Kandhkot, the taluka headquarters, is a rural town with a population of about 2,000, surrounded by dry-crop cultivation. On the east of the town there is an excavation about 100 feet square, which was fed by a canal distributary prior to 1927. It is said that malaria has decreased since the water from this was cut off. About 100 yards to the east there is another large tank containing much vegetation, where larvae of *A. culicifacies* and *A. subpictus* were found in large numbers (September 1930). On the west and south of the town are a number of vegetable gardens in which are situated many irrigation wells. In two of these larvae of *A. stephensi* were found. This species was also found in one of the numerous wells in the town itself. Larvae of *A. culicifacies* and *A. subpictus* were found in some borrow-pits between the periphery of the town and the vegetable gardens above mentioned. The subsoil water level was 18 to 20 feet.

First survey (pre-epidemic).—In January 1928 the splenic index was 28 (92 observations).

Second survey (pre-epidemic).—In November 1928 the splenic index was 10 (204 observations), the apex-umbilicus measurement of the average enlarged spleen being 8·8 cm. The parasite index was 23 (100 observations). Out of 54 adult anophelines caught in the town, 33 were *A. culicifacies*, 20 *A. subpictus* and one *A. pulcherrimus*. Twenty *A. culicifacies* were dissected, of which one was found infected (gut only).

Third survey (post-epidemic).—In September 1930 the splenic index was 84 (201 observations), the apex-umbilicus measurement of the average enlarged spleen being 7·6 cm. The parasite index was 60 (50 observations). Out of 122 adult anophelines collected, 26 were *A. culicifacies*, 75 *A. subpictus*, 3 *A. pulcherrimus* and 3 *A. stephensi*. Twenty *A. culicifacies* were dissected, out of which one was found infected (salivary glands only).

HAYBAT is a village with a population of about 450, situated on a slightly elevated site four miles south of Kandhkot, in the midst of jungle. There are patches of dry-crop cultivation extending to within 400 yards of the village. The 'Sind dhoro,' or old channel of the Indus referred to above, runs about one mile to the north of the village. The nearest canal distributary is about three-quarters of a mile distant. The subsoil water level was 12 feet (September 1930).

First survey (pre-epidemic).—In January 1928 the splenic index was 26·5 (39 observations).

Second survey (pre-epidemic.)—In November 1928 the splenic index was 5·7 (70 observations), the apex-umbilicus measurement of the average enlarged

spleen being 8·5 cm. The parasite index was 17·2 (29 observations). Out of 20 adult anophelines collected 17 were *A. culicifacies,* and the rest *A. subpictus.*

Third survey (post-epidemic).—In September 1930 the splenic index was 88 (58 observations), the apex-umbilicus measurement of the average enlarged spleen being 6·9 cm. The parasite index was 20 (20 observations). Out of 42 anophelines captured, 13 were *A. culicifacies,* and the rest *A. subpictus.*

DARI is a village with a population of about 400, situated in the midst of forest eight miles south-west of Kandhkot, and about 600 yards from the 'Sind dhoro.' This channel forms a large swampy area, in which larvae of *A. culicifacies* and *A. subpictus* were found. Patches of dry-crop cultivation were seen in the neighbourhood of the village. The subsoil water level was 6 to 8 feet (September 1928).

First survey (pre-epidemic).—In November 1928 the splenic index was 20·9 (110 observations), the apex-umbilicus measurement of the average enlarged spleen being 8 8 cm. The parasite index was 22 5 (40 observations). Out of 25 adult anophelines collected, 20 were *A. culicifacies* and the remainder *A. subpictus.*

Second survey (post-epidemic).—In September 1930 the splenic index was 92 (100 observations), the apex-umbilicus measurement of the average enlarged spleen being 6 3 cm. Out of 65 adult anophelines caught, 26 were *A. culicifacies,* 34 *A. subpictus,* and 5 *A. pulcherrimus.*

GHAUSPUR is a village with a population of about 1,500, situated just outside the Kashmor bund and 50 yards from the edge of the 'Sind dhoro,' about 12 miles south-west of Kandhkot. The 'dhoro' forms a large almost stagnant swamp after the termination of the inundation period about 200 yards broad. Larvae of *A. culicifacies* and *A. subpictus* were found breeding in large numbers along its edge (September 1930). Towards the north and west of the village dry-crop cultivation extends to within 400 yards of its periphery. On the western side of the village a few borrow-pits were seen, in which *A. culicifacies* and *A. subpictus* were breeding.

First survey (pre-epidemic).—In November 1928 the splenic index was 62·9 (112 observations), the apex-umbilicus measurement of the average enlarged spleen being 7 8 cm. The parasite index was 44 (100 observations). Out of 48 anophelines captured, 31 were *A. culicifacies,* 13 *A. subpictus* and 4 *A. pulcherrimus.*

Second survey (post-epidemic).—In September 1930 the splenic index was 91·7 (120 observations), the apex-umbilicus measurement of the average enlarged spleen being 7·7 cm. The parasite index was 25 (40 observations). Out of 90 anophelines captured, 28 were *A. culicifacies,* 48 *A. subpictus* and 14 *A. pulcherrimus.*

3. *Thul Taluka.*

This taluka lies immediately to the west of Kandhkot, and has an area of 497 square miles, with a population of 49,924 (in 1921).

THUL, the taluka headquarters, is a rural town with a population of about 2,000, situated on the bank of a branch of the Begari canal, in the midst of dry-crop cultivation. There are a number of borrow-pits at the periphery of the town, in three of which larvae of *A. culicifacies* were collected (September 1930). Larvae of *A. culicifacies* and *A. subpictus* were also found in a small canal distributary supplying some vegetable gardens, and the former species was also found breeding along a minor canal branch called the Nasar Wah. The subsoil water level was 13 feet.

First survey (pre-epidemic).—In January 1928 the splenic index was 24 (66 observations).

Second survey (post-epidemic). In September 1930 the splenic index was 87·3 (181 observations), the apex-umbilicus measurement of the average enlarged spleen being 7·9 cm. The parasite index was 34 (50 observations). Out of 29 adult anophelines caught, 25 were *A. culicifacies*, 3 *A. subpictus* and 1 *A. pulcherrimus*. Out of 18 *A. culicifacies* which were dissected, one was found with both salivary glands and gut infected, and two with gut infections only.

CHANA is a village with a population of about 700, situated 8 miles south-west of Thul, in the midst of dry-crop cultivation. The Begari canal flows four miles to the south of the village, and one of its branches runs half a mile north of it. Small canal distributaries run in the immediate vicinity of the village, and there are a large number of excavations close to the periphery, in two of which larvae of *A. culicifacies* and *A. subpictus* were found (September 1930). A pond about 60 feet long and 60 feet broad at one corner of the village was also found breeding *A. culicifacies*. The subsoil water level was 7 feet.

This village was not visited prior to the epidemic. In September 1930 the splenic index was 92·6 (121 observations), the apex-umbilicus measurement of the average enlarged spleen being 7·2 cm. The parasite index was 56 (25 observations). Out of 41 adult anophelines captured, 17 were *A. culicifacies*. 23 *A. subpictus* and 1 *A. pulcherrimus*. Nine of the first named species were dissected with negative results.

MIRPUR is a village with a population of about 1,400, situated in the midst of dry-crop cultivation six miles south-west of Thul. Along the course of a canal distributary which flows close to the village a number of borrow-pits were seen, in two of which larvae of *A. culicifacies* were found (September 1930). The subsoil water level was 9 to 14 feet.

This village was not visited before the epidemic. In September 1930 the splenic index was 86·2 (123 observations), the apex-umbilicus measurement

of the average enlarged spleen being 7 7 cm. The parasite index was 48 (25 observations). Out of 35 adult anophelines captured, 15 were *A. culicifacies,* 17 *A. subpictus* and 3 *A. pulcherrimus.*

Mir Hasan is a village with a population of about 150, situated in the midst of dry-crop cultivation three miles north-east of Thul. Larvae of *A. culicifacies* were found in a small canal distributary running close to the periphery of the village. The subsoil water level was 9 feet (September 1930).

First survey (pre-epidemic).—In January 1928 the splenic index was 33 (27 observations).

Second survey (post-epidemic).—In September 1930 the splenic index was 83 (53 observations), the apex-umbilicus measurement of the average enlarged spleen being 9 3 cm.

Garhi Hasan is a village with a population of about 250, situated six miles north of Thul. A canal distributary flows close to the village, and by the side of this is a tank about 60 feet square, in which larvae of *A. culicifacies* were found. There is rice cultivation 600 yards north of the village. The subsoil water level was 3 feet.

This village was not visited before the epidemic. In September 1930 the splenic index was 86 (57 observations), the apex-umbilicus measurement of the average enlarged spleen being 8 8 cm. The parasite index was 30 (10 observations only).

4. *Jacobabad Taluka.*

This taluka lies between Thul on the east and Shahdadkot on the west, and has an area of 461 square miles, with a population of 75,077 (in 1921). The land is low-lying, and there is more rice cultivation than in any other taluka of the district.

Jacobabad, the headquarters of the taluka, and of the Upper Sind Frontier district, has a population of about 12,000, and is situated in the midst of groves and gardens. To the east and south of the town there is rice cultivation. A small canal distributary flows almost through the centre of the town, giving off branches at various points. Another distributary almost surrounds the town. These two channels supply irrigation water to the fruit and vegetable gardens in the town and in its immediate vicinity. In the centre of the town there is a tank about 50 yards in length, fed by a small distributary; in this larvae of *A. subpictus* were found. Almost all the canal distributaries contained much rank vegetation in October 1930, and larvae of *A. culicifacies* were found in many of them. The subsoil water level varied from 15 to 20 feet.

First survey (pre-epidemic).—In January 1928 the splenic index was 17 (100 observations).

Second survey (post-epidemic).—In October 1930 the splenic index was 64·6 (347 observations), the apex-umbilicus measurement of the average

enlarged spleen being 8·6 cm. The observations were made at four different schools, the splenic indices of these varying from 50 to 80. The parasite index among children from the Municipal Branch School (where the splenic index was 80) was 34 (50 observations). Out of 56 adult anophelines captured, 42 were *A. culicifacies,* 8 *A. subpictus* and 6 *A. pulcherrimus.* Sixteen *A. culicifacies* were dissected, one of which was found to have a gut infection.

JATOHI is a village with a population of about 250, situated two miles north of Jacobabad. There is jungle in the immediate neighbourhood of the village, and 200 yards from it there is some rice cultivation. The subsoil water level was 5 feet (October 1930). A canal distributary runs 100 yards from the edge of the village, and in it larvae of *A. culicifacies* were found.

First survey (pre-epidemic).—In January 1928 the splenic index was 32 (25 observations).

Second survey (post-epidemic).—In October 1930 the splenic index was 89 (55 observations), the apex-umbilicus measurement of the average enlarged spleen being 7 7 cm. Out of 14 adults examined, 6 showed splenic enlargement. Out of 32 adult anophelines captured, 10 were *A. culicifacies,* and the rest *A. subpictus.*

SADIK BANGAR is a village with a population of about 250, situated 3 miles north of Jacobabad. There is rice cultivation at a distance of 100 yards from the village, and a canal distributary flows close to it on the southern side. Larvæ of *A. culicifacies* were found in a borrow-pit close to the edge of the village (October 1930). The subsoil water level was 5 feet.

This village was not visited before the epidemic. In October 1930 the splenic index was 76·5 (17 observations only), the apex-umbilicus measurement of the average enlarged spleen being 7 2 cm. Out of 6 adults examined, one had an enlarged spleen. Out of 25 adult anophelines captured, 11 were *A. culicifacies,* and the remainder *A. subpictus.*

DIL MURAD KHOSO is a village with a population of about 350, situated six miles north of Jacobabad. The main crops are juari, bajri and wheat, but a little rice is also grown. A canal distributary runs close to the village, and larvae of *A. culicifacies* were found in some pools formed by leakage from this.

This village was not visited in the pre-epidemic period. In October 1930 the splenic index was 81·8 (77 observations), the apex-umbilicus measurement of the average enlarged spleen being 8·7 cm. Seven out of twelve adults examined also had enlarged spleens. Out of 23 adult anophelines captured, 9 were *A. culicifacies,* and the remainder *A. subpictus.*

BHALAIDINA ABAD is a village with a population of about 900, situated in the midst of dry-crop cultivation 8 miles south-west of Jacobabad. There are a number of groves and gardens surrounding the village. A canal distributary runs through the centre of the village, and larvae of *A. culicifacies* were found

in two of the borrow-pits lying along its course. The subsoil water level was 6 feet.

This village was not visited before the epidemic. In October 1930 the splenic index was 79 3 (92 observations), the apex-umbilicus measurement of the average enlarged spleen being 7 5 cm. The parasite index was 52·5 (40 observations). Out of 56 adult anophelines captured, 24 were *A. culicifacies*, and the remainder *A. subpictus*.

RAMZANPUR is a village with a population of about 280, situated in the midst of dry-crop cultivation 10 miles south-west of Jacobabad. A canal distributary runs within 50 yards of the periphery of the village on the south-east side, and in it larvae of *A. culicifacies* were collected. There are no wells in the neighbourhood.

The village was not visited before the epidemic. In October 1930 the splenic index was 62 2 (37 observations), the apex-umbilicus measurement of the average enlarged spleen being 9 2 cm. The parasite index was 40 (10 observations only). Out of 14 adult anophelines captured, 5 were *A. culicifacies*, 7 *A. subpictus* and 2 *A. pulcherrimus*.

MAULABAD is a village with a population of about 350, situated in the midst of dry-crop cultivation 6 miles south-west of Jacobabad. A canal distributary almost surrounds the village, but no larvae were found in it, nor in some borrow-pits along its course. The subsoil water level was 10 feet.

The village was not visited before the epidemic. In October 1930 the splenic index was 70 (60 observations), the apex-umbilicus measurement of the average enlarged spleen being 8 1 cm. The parasite index was 65 (20 observations). Out of 20 adult anophelines captured, 8 were *A. culicifacies* and the remainder *A. subpictus*.

5. *Shahdadkot Taluka.*

This is the westernmost taluka of the district, and has an area of 619 square miles, with a population of 35,116 (in 1921). It is divided into two parts by the Eden Begari canal, the land to the west of this known as the Sir Amani tract, being exposed to hill floods. The survey was confined to villages in the plains area situated to the east of the canal, and was carried out in October 1930. The taluka was not visited before the occurrence of the epidemic of 1929.

SANDO is a village with a population of about 360, situated 5 miles south-west of Shahdadkot, and surrounded by ricefields. There is a canal distributary flowing about 200 yards from the periphery of the village on the eastern side. The splenic index was 93 (30 observations), the apex-umbilicus measurement of the average enlarged spleen being 8·0 cm. The parasite index was 45 (20 observations).

CHANGAL is a village with a population of about 150, situated 3 miles south-west of Shahdadkot, in the midst of ricefields. A canal distributary runs close to the village on its northern side. The splenic index was 80 (25 observations), the apex-umbilicus measurement of the average enlarged spleen being 9·4 cm.

KOT ALI NAWAZ is a village with a population of about 100, situated 3½ miles south-west of Shahdadkot. There is rice cultivation about 100 yards from the village. The subsoil water level was 8 feet. The splenic index was 72 (22 observations), the apex-umbilicus measurement of the average enlarged spleen being 10 2 cm.

AITBAR KHAN CHANDIA is a village with a population of about 320, situated in the midst of dry-crop cultivation, 5 miles east of Shahdadkot. There is some rice cultivation half a mile to the south. The subsoil water level was 10 feet. The splenic index was 90 (30 observations), the apex-umbilicus measurement of the average enlarged spleen being 6·4 cm.

GOT DARYAKHAN is a village with a population of about 100, situated 6 miles east of Shahdadkot. Most of the surrounding cultivation is dry-crop, but a small amount of rice is also grown. The subsoil water level was 10 feet. The splenic index was 70 (20 observations), the apex-umbilicus measurement of the average enlarged spleen being 10·3 cm.

SOBDAR MASTOI is a village with a population of about 120, situated in the midst of dry-crop cultivation, 5 miles east of Shahdadkot. The subsoil water level was 9 feet. The splenic index was 75 (20 observations), the apex-umbilicus measurement of the average enlarged spleen being 8 5 cm.

CHAKIANI is a village with a population of about 950, situated in the midst of dry-crop cultivation, 4 miles south-east of Shahdadkot. The splenic index was 87 5 (40 observations), the apex-umbilicus measurement of the average enlarged spleen being 9·3 cm.

SILRA is a village with a population of about 450, situated 3 miles east of Shahdadkot, and surrounded by dry-crop cultivation. The splenic index was 80 (35 observations), the apex-umbilicus measurement of the average enlarged spleen being 9·3 cm.

SHAHDADKOT, the taluka headquarters, is a rural town with a population of about 5,500, situated in the midst of dry-crop cultivation on the left bank of a branch of the Ghar canal. Distributaries from this surround the town, and there is a pond about 60 yards square on the eastern side, in which larvae of *A. subpictus* were found. There are two other large ponds, one on the west and one about 200 yards from the southern side of the town. The subsoil water level was 10 to 15 feet. The splenic index was 81·3 (365 observations), the apex-umbilicus measurement of the average enlarged spleen being 9·1 cm. The parasite index was 48 (50 observations).

Khan Mohamed Jamali is a village with a population of about 130, situated in the midst of dry-crop cultivation, 6 miles north-west of Shahdadkot. All the potential breeding-places were dry at the time of the survey. The splenic index was 80 6 (31 observations), the apex-umbilicus measurement of the average enlarged spleen being 10·0 cm.

Khuda Buksh Jamali is a village with a population of about 100, situated in the midst of dry-crop cultivation, 6 miles north-west of Shahdadkot. The splenic index was 74 (23 observations), the apex-umbilicus measurement of the average enlarged spleen being 10 6 cm.

Imam Buksh is a village with a population of about 90, situated 7 miles north-west of Shahdadkot, and surrounded by ricefields. Larvae of *A. culicifacies* were found in the bed of a canal distributary which runs 300 yards to the east of the village. The subsoil water level was 4 feet. The splenic index was 76 (25 observations), the apex-umbilicus measurement of the average enlarged spleen being 9 1 cm.

Habibullah Khan Jamali is a village with a population of about 170 situated in the midst of rice cultivation, 8 miles north-west of Shahdadkot. The splenic index was 76 2 (34 observations), the apex-umbilicus measurement of the average enlarged spleen being 10 6 cm.

Kamal Bhati is a village with a population of about 100, situated 6 miles north-east of Shahdadkot, and surrounded by dry-crop cultivation. The splenic index was 86 7 (15 observations), the apex-umbilicus measurement of the average enlarged spleen being 8 8 cm.

Jiand Jarwar is a village with a population of about 250, situated 6 miles north-east of Shahdadkot, in the midst of rice cultivation. Larvae of *A. culicifacies* were found in the bed of the Sukkur canal, which flows about 440 yards to the north of the village. The subsoil water level was 6 feet. The splenic index was 77 8 (45 observations), the apex-umbilicus measurement of the average enlarged spleen being 9 7 cm.

Metha Jamali is a village with a population of about 60, situated 6 miles north-east of Shahdadkot, and surrounded by dry-crop cultivation. The splenic index was 70 (10 observations only), the apex-umbilicus measurement of the average enlarged spleen being 10 2 cm.

Shahpur is a village with a population of about 170, situated 5 miles north-east of Shahdadkot, in the midst of dry-crop cultivation. The splenic index was 90 (30 observations), the apex-umbilicus measurement of the average enlarged spleen being 9 8 cm.

Anopheline mosquitoes.

During the course of the 1930 survey 832 adult anophelines were captured in the various villages, of which 374 (45 per cent) were *A. culicifacies*, 422 (51 per cent) were *A. subpictus*, 35 (4 per cent) were *A. pulcherrimus*, and 3

were *A. stephensi.* The proportion of females to males was 5 to 1 in the case of *A. culicifacies,* 3 to 1 in the case of *A. subpictus,* and 4 to 1 in the case of *A. pulcherrimus.* The larvae of *A. culicifacies* were especially numerous in small canal distributaries containing much vegetation, and where such were present the number of adults in the villages concerned was correspondingly greater.

Dissections.—Out of 83 specimens of *A. culicifacies* dissected in the course of the survey, 2 (2·4 per cent) were found with sporozoites in the salivary glands, and 5 (6·0 per cent) with gut infections. The total number found infected was 6 (7·2 per cent).

There is no doubt that, as is the case throughout the province of Sind, *A. culicifacies* is the principal, if not the only, anopheline concerned in the transmission of malaria.

Discussion of results.

It has been repeatedly shown in the course of this inquiry that during the inter-epidemic periods the amount of endemic malaria varies widely in different parts of Sind, depending on local conditions. In the case of the Upper Sind Frontier district the splenic indices recorded before the epidemic of 1929 were generally comparatively low, varying from 5 to 33. Ghauspur was an exception, the splenic index in November 1928 being 62·9. It is evident that this village is permanently hyperendemic, a fact which is explained by its position almost on the bank of the 'Sind dhoro,' or former channel of the Indus, which forms an ideal permanent breeding-place for *A. culicifacies.*

The observations carried out in the autumn of 1930, one year after the epidemic (which affected the whole of northern Sind), showed that the spleen rates throughout the district, whatever they had been before the epidemic, were now raised with remarkable uniformity to figures between 70 and 90. The index for Kashmor taluka was 81 0, for Kandhkot 88·1, for Thul 87·8, for Jacobabad 71·0, and for Shahdadkot 81 0. It should be mentioned that the figure for Jacobabad is certainly too low, as 347 of the 685 children examined came from the headquarter town of the taluka, and figures from towns are of course invariably lower than those from the small villages. The combined splenic index for the whole district was 81·0 (2,647 observations).

Considerable differences were noted in the size of the average enlarged spleen, the apex-umbilicus measurement after the epidemic varying from 7·1 cm. in Kandhkot taluka to 9·2 in Shahdadkot. It is also interesting to note that in the case of four villages where spleen measurements were carried out before the epidemic, three of them, in which the pre-epidemic spleen rate was low (between 5·7 and 20 9), showed a great increase in the size of the average enlarged spleen after the epidemic; whilst the fourth, Ghauspur, which had a pre-epidemic spleen rate of 62·9, showed practically no change in the size of the average enlarged spleen after the epidemic.

A very large number of observations have been made in various parts of northern Sind during the course of the epidemic and subsequent to it, and it is felt that a full discussion of the subject should be postponed until the conditions have gone back to the normal state in which they are in the inter-epidemic period.

SUMMARY.

(1) An account is given of the results of malaria surveys carried out in the Upper Sind Frontier district (*a*) before the epidemic of 1929, and (*b*) one year after the epidemic.

(2) Before the epidemic splenic indices in the various villages were generally comparatively low, though some showed hyperendemic figures due to local conditions permanently favourable to transmission of malaria.

(3) The splenic indices recorded in the year following the epidemic were uniformly high, varying from 70 to 90, the mean index for 2,647 observations being 81·0.

(4) A full discussion of the results is postponed until further observations on the course of the epidemic have been made, and until conditions have once more approached their normal inter-epidemic status.

(5) As in other parts of Sind, *A. culicifacies* is considered to be the principal, if not the sole, insect vector of malaria in the district.

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THE SIGNIFICANCE OF THE VARIOUS DEGREES OF SPLENIC ENLARGEMENT IN MALARIOUS COMMUNITIES.

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CONTENTS.

PART I

INTRODUCTORY.

Introduction.

Since the first use was made of the spleen rate as a measure of malarial insalubrity by Dempster (1847), measurements have been made of the size of the enlarged spleen. Dempster tabulated the results of his measurements of enlarged spleens under five headings, ordinary, medium, large, very large and small, but drew no inferences of value from the frequencies of the different sizes observed. Subsequent workers adopted a system of measurement of the projection of the enlarged spleen below the costal margin in terms of

finger-breadths, and this method came into very general use. Apart from the observation that large spleens were common at high spleen rates, however, they were unable to obtain information of any use to them from their records. Ross (1908) advanced the position by estimating the weight of spleens showing various degrees of enlargement. He was thus able, by attributing to every class of spleen its approximate relative weight, to calculate the average increase in splenic mass in a community, and he used this as an additional measure of the severity of malaria.

The next important step in our knowledge of the cause of the variations in the degree of splenic enlargement was made by Christophers (1916). He made his measurements in finger-breadths projection below the costal margin, correlated these with careful estimations of the weight of enlarged spleens, and was thus able to attribute a definite weight to each grade of enlargement. He then constructed a 'standard splenic diagram' showing the frequency with which spleens of various weights were seen at varying spleen rates. From this and other evidence he formulated his 'splen' theory, which postulated that each infection with malaria was responsible for a definite mean increase in splenic mass. According to this theory the distribution of large spleens therefore followed the laws which govern 'overlapping' of infections in random distribution.

Our knowledge of this subject remained in this position until Schüffner (1921) and Christophers (1921) put forward the reasons why it was desirable that a reliable method of measuring the enlarged spleen should be devised. In the opinion of both of these workers the method adopted should take some account of the size of the individual examined, for a spleen of, say, 6 cm. costal margin projection represented a much greater relative enlargement in a small child than in an adult. The measurements made should be accurate, they should be reliable and the method should be easily carried out in the field. Several methods were devised by Schüffner (1921), Kuno (1923), Christophers and Khazan Chand (1924) and other workers. The method adopted by Christophers and Khazan Chand consisted, briefly, of triangulation of the position of the apex of the spleen by measurement of its distance from the umbilicus and from the median line of the body. At the time that these measurements were taken some anthropometric measurement, such as the sitting height or the nipple umbilicus line was also taken. This was used to correct the measurements of the size of the spleen for the size of the child.

This system has been adopted by the Malaria Survey of India in all its important surveys, and many thousands of enlarged spleens have been measured in this way. The purpose of this paper is to take a number of these measurements, and to analyse them statistically, showing the frequency of the different degrees of enlargement under different conditions, and attempting to distinguish the causes of variations from the normal distribution curve.

Sources of statistics.

Records of measurements of enlarged spleens have been taken from the following sources:—(1) two series of children examined by Christophers (1924); the first of these was in Nalbari, when 80 children were examined and 75 showed splenic enlargement, and the second in Singhbhum, where 182 children were examined, of whom 126 showed splenic enlargement. Both of these places were taken by Christophers as typically hyperendemic. They were visited at the end of the 1921 malaria season. (2) A series of 1,059 children, of whom 604 had enlarged spleens, examined by Macdonald (1926). The examinations were made in Sierra Leone, West Africa, over a complete year. This again is an example of hyperendemicity. (3) A series of 137 children of whom 90 proved positive, examined by the author in Sierra Leone in the autumn of 1926. (4) A series of 358 children, of whom 107 proved positive, examined by the author in Kathiawar just before the commencement of the 1930 malaria season. This is an example of seasonal malaria. (5) A series of 1,766 children, of whom 1,015 showed splenic enlargement, examined in the Sibsagar District of Assam by Macdonald and Chowdhury (1931) in June 1930. This is an example of hyperendemic malaria. (6) A series of 4,371 children, of whom 1,455 proved positive, examined by Macdonald and Majid (1931) in villages of the Karnal District, Punjab. This is an example of inter-epidemic seasonal malaria. Examinations were made both during the malaria and the non-malaria seasons. (7) A series of 20,462 children, of whom 9,223 showed splenic enlargement, examined by Covell and Baily (1931). These workers have for some years carried out extensive examinations in Sind, and have included in their surveys examples of severe epidemic malaria, post-epidemic hyperendemicity during both the malaria and the non-malaria seasons, and inter-epidemic malaria during the malaria and the non-malaria seasons. These results are as yet mostly unpublished, and the author is deeply indebted for permission to abstract and make use of their records.

It will be seen that measurements are available for a very varied series of types of malaria, at all seasons of the year, and that the figures are sufficiently large to make analyses reliable. The total number of children included in the analysis is 28,015, of whom 12,695 had a palpable enlargement of the spleen.

Method of analysis.

The corrected apex-umbilicus (A-U) measurements only have been used in this analysis, the apex-mid-line measurements being ignored. The larger the spleen becomes, and the nearer it approaches to the umbilicus, the smaller this measurement becomes. Spleens recorded as being 'just palpable but not reaching to the costal margin' have been omitted in the calculation both of the frequency distribution and of the spleen rate. They are in negligible numbers

except in series (2) above. Spleens projecting below the umbilicus, which are in all cases few in number, have been included with those recorded as reaching to the umbilicus.

The results of each survey of a village or other unit have been classified according to the spleen rate of the unit, classes being used according to whether the spleen rate fell between 1 and 10 per cent, 11 and 20 per cent, 21 and 30 per cent, etc. From these, frequency tables and polygons have been prepared showing the frequency of each size of spleen at different spleen rates.

The results have then been classified according to the type of malaria they represent, and frequency tables prepared for each type. For this purpose six divisions and subdivisions have been employed, as follows:—(1) *Static malaria:* this division includes all records from districts in which there is a normal malaria season of six months or longer, and which, on account of the normal severity of malaria, do not show marked seasonal exacerbations. Most of these areas would normally be classified as '*hyperendemic,*' though low spleen rates are sometimes found in places distant from the breeding places of dangerous carrier species of anophelines. The records from Singhbhum, Nalbari, Sierra Leone and Assam are included in this group. (2) *Seasonal malaria,* (*a*) *malaria season* and (*b*) *non-malaria season:* this group includes records from districts in which there is normally a short malaria season, during which the population suffers severely, followed by a relatively long period of quiescence. It excludes examples of epidemic malaria and post-epidemic hyperendemicity. The records from the Punjab, some of those from Sind by Covell and Baily, and those from Kathiawar, are included in this group. In all cases the malaria season has been counted as lasting from September to December, and the non-malaria season from January to August. (3) *Epidemic malaria:* certain districts in India are liable to occasional fulminant epidemics of malaria, greatly exceeding in severity the normal autumnal outbreaks. They have been fully described by Christophers (1911). The records of Covell and Baily include an example of this in the northern portion of Sind in 1929. (4) *Post-epidemic hyperendemicity,* (*a*) *malaria season* and (*b*) *non-malaria season:* this group includes all the results of examinations made by Covell and Baily in the area affected by the 1929 epidemic, after the termination of that epidemic. The division into malaria season and non-malaria season is the same as that used in the case of seasonal malaria.

From a preliminary inspection it was observed that the spleen sizes might conveniently be divided into four groups; those with an apex umbilicus measurement of (1) 12–15 cm., (2) 9–11 cm., (3) 6–8 cm., and (4) 0–5 cm. The last group, as already stated, includes all those spleens projecting beyond the umbilicus. The percentage of enlarged spleens, in each type of malaria, at each grade of spleen rate, falling into each of these groups has then been

compared with the percentage in all other types of malaria, with this spleen rate. In calculating the probable error of the difference between these percentages, the formula for the probable error of a difference given by Caradog Jones (1924) has been employed, and a difference exceeding three times its probable error has been considered as significant. At the same time undue reliance has not been placed on isolated examples of significant differences, as it is realized that there are many more forces at work than are indicated by the simple classification of malaria into types employed here.

PART II.

Results.

General.

The total number of children examined, the number showing enlarged spleens, and the percentage frequency of each degree of splenic enlargement for each grade of spleen rate are set out in Table A, in the Appendix. They are illustrated by two sets of figures, (1) figures 1 to 10, which are frequency polygons based on the frequency tables, and (2) figure 11, which shows in diagrammatic form the frequency of each size of spleen at varying spleen rates. The chief points to be observed from these are:—(1) at all spleen rates over 20 per cent the frequency polygons are definitely bimodal, 9 cm. A-U spleens being always in defect as compared with 8 and 10 cm. A-U. spleens. At spleen rates below 20 per cent there is an indication of this bimodality in a marked skew to the right. (2) The relative importance of the two modes varies, that representing the larger spleens becoming gradually more important as the spleen rate increases. From figure 11 it will be observed that (3) spleens of 11, 12, 13, 14, and 15 cm. A-U are in excess at spleen rates between 20 and 40 per cent, and in marked defect at high spleen rates. (4) 9 and 10 cm. A-U spleens form a fairly constant proportion of the spleen composition at all spleen rates below 80 per cent. They are less numerous at spleen rates higher than this. (5) 8 cm. A-U spleens slightly increase in numbers with increasing spleen rates. (6) 6 and 7 cm. A-U spleens show a slight decrease in frequency as the spleen rate increases from 5 to about 35 per cent. They increase gradually as the spleen rate increases from this figure to 75 per cent, and then show a marked increase as the spleen rate rises higher. (7) Spleens of 5 cm A-U or larger are rare at low spleen rates, but increase markedly in importance at spleen rates over 75 per cent.

The significance of most of these points will be discussed when other evidence has been considered, but attention may be drawn here to the fact that the spleen composition at very low spleen rates, below 20 per cent, is in some ways irregular and resembles more that at 45 to 55 per cent, than that at 25 or 35 per cent. There is, for instance, a deficiency of 12 to 15 cm. A-U

spleens, and an excess of some of the larger sizes. The author believes this to be due to the fact that there is no such thing as a homogeneous spleen rate below, say, 15 per cent, at any rate during the malaria season. When we come across these low spleen rates we are probably dealing in reality with a number of scattered foci of malarial infection in a population the greater part of which is not exposed to infection. Although, therefore the spleen rate for the whole area may be very low, the spleen composition is representative of a higher rate.

Comparative analysis in different types of malaria.

Tables B to G, in the Appendix give the full details of the number of children examined, the number showing enlargement of the spleen, and the percentage frequency of each size of spleen, for each type of malaria at all spleen rates for which observations are available. These tables are summarized in the tables used in the text, all of which are constructed on the same principle. They give (1) the percentage frequency of the size of spleen under discussion, in the type of malaria specified at various spleen rates, (2) the percentage frequency of this size of spleen in all other types of malaria, excluding that under discussion for the same spleen rates, (3) the difference between these percentages, with (4) its probable error, and (5) the significance of this difference. In all cases records in which the number of observations is obviously too small to be of value are omitted from these tables.

1. *Spleens of 12–15 cm. A-U measurement.*—These are in definite marked excess in static malaria (Table I*a*). There is a single significant record of

TABLE I.

The difference between the percentage frequency of 12–15 cm. A-U spleens in specified types of malaria from that in all other types.

Spleen rate.	Percentage of 12–15 cm. A-U spleens in this type of malaria.	Percentage of 12–15 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*a*) Static malaria.			
91–100 ..	7·0	2·6	+4·4	1·2	Significant.
81–90 ..	14·6	7·6	+7·0	1·4	Significant.
71–80 ..	11·4	8·3	+3·1	1·2	Not significant.
61–70 ..	15·0	8·8	+6·2	0·9	Significant.
51–60 ..	35·9	16·0	+19·9	2·6	Significant.
41–50 ..	19·6	11·0	+8·6	3·0	Not significant.
31–40 ..	23·1	15·1	+8·0	1·7	Significant.

TABLE I—*contd.*

Spleen rate.	Percentage of 12–15 cm. A-U spleens in this type of malaria.	Percentage of 12–15 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*b*) Post-epidemic hyperendemicity, malaria season.			
91–100 ..	0	4·2	—4·2	1·2	Significant.
81–90 ..	11·1	7·3	+3·8	1·0	Significant.
51–60 ..	12·4	18·0	—5·6	2·0	Not significant.
31–40 ..	16·5	17·1	—0·6	2·6	Not significant.
		(*c*) Post-epidemic hyperendemicity, non-malaria season.			
91–100 ..	3·0	3·9	—0·9	0·9	Not significant.
81–90 ..	9·1	8·5	+0·6	1·4	Not significant.
71–80 ..	6·9	9·1	—2·2	1·9	Not significant.
61–70 ..	11·8	9·1	+2·7	0·7	Significant.
51–60 ..	8·7	19·3	—10·6	1·6	Significant.
41–50 ..	14·4	10·5	+3·9	1·5	Not significant.
31–40 ..	9·3	18·6	—9·3	1·9	Significant.
		(*d*) Seasonal malaria, malaria season.			
81–90 ..	5·7	8·8	—3·1	2·1	Not significant.
71–80 ..	8·7	9·0	—0·3	1·2	Not significant.
61–70 ..	6·1	10·8	—4·7	0·9	Significant.
51–60 ..	18·4	17·1	+1·3	1·9	Not significant.
41–50 ..	11·6	11·3	+0·3	1·3	Not significant.
31–40 ..	16·4	17·1	—0·7	2·6	Not significant.
21–30 ..	21·8	16·5	+5·3	2·1	Not significant.
11–20 ..	13·6	15·2	—1·6	2·1	Not significant.

TABLE I—*concld.*

Spleen rate.	Percentage of 12–15 cm. A-U spleens in this type of malaria.	Percentage of 12–15 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*e*) Seasonal malaria, non-malaria season.			
71–80 ..	9·0	8·9	+0·1	1·7	Not significant.
61–70 ..	8·3	10·2	—1·9	1·3	Not significant.
51–60 ..	7·6	19·5	—11·9	1·7	Significant.
41–50 ..	6·5	13·0	—6·5	1·3	Significant.
31–40 ..	16·6	17·2	—0·6	1·7	Not significant.
21–30 ..	16·2	20·5	—4·3	2·0	Not significant.
11–20 ..	16·4	12·6	+3·8	1·8	Not significant.
		(*f*) Epidemic malaria			
91–100 ..	4·8	3·2	+1·6	1·4	Not significant.
81–90 ..	4·1	10·7	—6·6	1·1	Significant.
71–80 ..	11·5	7·2	+4·3	1·0	Significant.
61–70 ..	6 0	11·1	—5·1	0 9	Significant.
51–60 ..	7·9	21·6	—13·7	1·4	Significant.
41–50 ..	11·6	11·1	+0·5	1·2	Not significant.
31–40 ..	12·8	18·0	—5·2	1·9	Not significant.
21–30 ..	9·2	19·4	—10·2	3·4	Significant.

excess in post-epidemic hyperendemicity, malaria season (Table I*b*), non-malaria season (Table I*c*) and in epidemic malaria (Table I*f*).

They are in defect in post-epidemic hyperendemicity, non-malaria season, at spleen rates below 60 per cent, in epidemic malaria except for the one record mentioned above, and in seasonal malaria, non-malaria season. There is a single significant record of defect in seasonal malaria, malaria season, and in post-epidemic hyperendemicity, malaria season, though both of these are doubtful, being isolated.

In dealing with this type of spleen attention may be drawn to the observation of Macdonald (1931) that in Assam the parasite rate in association with this size of spleen was normally lower than that seen with larger spleens.

Macdonald and Majid (1931) noted that spleens which when first seen were more than 10 cm. from the umbilicus were frequently only temporarily enlarged. It has been remarked previously that spleens of this size are commonest at low spleen rates.

2. *Spleens of* 9 *to* 11 *cm. A-U measurement.*—These are definitely in excess in epidemic malaria (Table II*d*) and in post-epidemic hyperendemicity, malaria season (Table II*a*). They are in defect in seasonal malaria, malaria and non-malaria seasons (Tables II*b* and II*c*). The results for static malaria and for post-epidemic hyperendemicity, non-malaria season, are erratic and are therefore not reproduced.

In this connection the following points may also be noted:—Covell and Baily (1927) noted that in a community of adults recently imported into a highly malarious area the modal size of spleen was smaller than in a community long resident there, though the spleen rate was much higher. The majority of the spleens seen by them in the recently imported group were of this size. In the tables and graphs given by Macdonald, describing work in Assam, it will be seen that this size of spleen, again, is less frequently associated with a positive blood than larger ones, and that they were most frequently associated with very low parasite counts of under 100 parasites per c.mm. They formed the modal size of spleen in the youngest children examined, and in the oldest, while in children aged three to four larger spleens were more common. The decrease in frequency of these spleens at spleen rates over 75 per cent has already been noted.

TABLE II.

The difference between the percentage frequency of 9 *to* 11 *cm. A-U spleens in specified types of malaria from that in all other types.*

Spleen rate.	Percentage of 9–11 cm. A-U spleens in this type of malaria.	Percentage of 9–11 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
(*a*) Post-epidemic hyperendemicity, malaria season.					
91–100 ..	29·2	27·0	+2·2	3·0	Not significant.
81–90 ..	35·1	33·3	+1·8	1·8	Not significant.
51–60 ..	50·0	41·0	+9·0	2·6	Significant.
31–40 ..	53·4	41·8	+11·6	3·4	Significant.

TABLE II—*concld.*

Spleen rate.	Percentage of 9–11 cm. A-U spleen in this type of malaria.	Percentage of 9–11 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*b*) Seasonal malaria, malaria season.			
81–90 ..	35·2	33 8	+1·4	3·5	Not significant.
71–80 ..	33·5	44·5	—11·0	2·0	Significant.
61–70 ..	36·5	43·1	—6·6	1·7	Significant.
51–60 ..	37·2	42·8	—5·6	2·4	Not significant.
41–50 ..	44·5	44·9	—0·4	2·1	Not significant.
31–40 .	50·0	42·1	+7·9	3·4	Not significant.
21–30 ..	44·4	46·1	—1·7	2·6	Not significant.
11–20 ..	47·2	43·8	+3·4	3·3	Not significant.
		(*c*) Seasonal malaria, non-malaria season.			
71–80 ..	41·4	42·0	—0·6	3·0	Not significant.
61–70 ..	37·6	42·0	—4·4	2·2	Not significant.
51–60 ..	36·0	43·5	—7·5	2·1	Significant.
41–50 ..	34·5	48·4	—13·9	2·2	Significant.
31–40 ..	40·0	43·6	—3·6	2·2	Not significant.
21–30 ..	45·8	45·1	+0·7	2·6	Not significant.
11–20 ..	40·7	50·2	—9·5	2·6	Significant.
		(*d*) Epidemic malaria.			
91–100 ..	22·9	28·0	—5·1	4·1	Not significant.
81–90 ..	31·5	22·6	+8·9	1·8	Significant.
71–80 ..	49·1	37·2	+11·9	1·8	Significant.
61–70 ..	42·8	41·7	+1·1	1·4	Not significant.
51–60 ..	47·4	39·6	+7·8	1·8	Significant.
41–50 ..	52·0	42·3	+9·7	2·1	Significant.
31–40 ..	47·1	41·8	+5·3	2·5	Not significant.
21–30 ..	49·2	45·0	+4·2	4·4	Not significant.

3. *Spleens of 6 to 8 cm. A-U measurement.*—These are in excess in post-epidemic hyperendemicity, non-malaria season (Table III*c*), while there is a single significant record of excess in seasonal malaria, non-malaria season (Table III*e*). They are in defect in post-epidemic hyperendemicity, malaria season (Table III*b*); although no record in this series is significant it may be taken as reliable as all the variations are of the same character, the odds being 16 to 1 against this being a chance effect. There are also significant records of defect in seasonal malaria, malaria season (Table III*d*), and in static malaria (Table III*a*). The records for epidemic malaria are too erratic to be of value.

TABLE III.

The difference between the percentage frequency of 6 to 8 cm. A-U spleens in specified types of malaria from that in all other types.

Spleen rate.	Percentage of 6–8 cm. A-U spleens in this type of malaria.	Percentage of 6–8 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
(*a*) Static malaria.					
91–100 ..	45·0	41·8	+3·2	3·3	Not significant.
81–90 ..	40·7	41·8	—1·1	2·5	Not significant.
71–80 ..	35·2	34·5	+0·7	2·1	Not significant.
61–70 ..	29·3	39·5	—10·2	1·4	Significant.
51–60 ..	27·4	37·2	—9·8	3·2	Significant.
41–50 ..	21·6	34·7	—13·1	4·6	Not significant.
31–40 ..	33·8	32·9	+0·9	2·1	Not significant.
(*b*) Post-epidemic hyperendemicity, malaria season.					
91–100 ..	41·7	42·5	—0·8	3·3	Not significant.
81–90 ..	40·8	42·1	—1·3	1·2	Not significant.
51–60 ..	30·6	37·3	—6·7	2·6	Not significant.
31–40 ..	30·1	33·4	—3·3	3·3	Not significant.

TABLE III—*concld.*

Spleen rate.	Percentage of 6–8 cm. A-U spleens in this type of malaria.	Percentage of 6–8 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
			(c) Post-epidemic hyperendemicity, non-malaria season.		
91–100 ..	43·2	41·8	+1·4	2·6	Not significant.
81–90 ..	43·1	41·4	+1·7	2·5	Not significant.
71–80 ..	45·7	33·8	+11·9	3·1	Significant.
61–70 ..	38·7	36·8	+1·9	1·1	Not significant.
51–60 ..	43·0	35·0	+8·0	2·1	Significant.
41–50 ..	33·8	34·4	—0·6	2·2	Not significant.
31–40 ..	35·5	32·6	+2·9	2·4	Not significant.
			(d) Seasonal malaria, malaria season.		
81–90 ..	39·8	41·8	—2·0	3·7	Not significant.
71–80 ..	37·3	33·9	+3·4	2·0	Not significant.
61–70 ..	39·5	37·2	+2·3	1·5	Not significant.
51–60 ..	29·6	37·6	—8·0	2·3	Significant.
41–50 ..	29·6	35·8	—6·2	2·0	Significant.
31–40 ..	29·8	33·4	—3·6	3·2	Not significant.
21–30 ..	28·0	30·5	—2·5	3·0	Not significant.
11–20 ..	30·7	33·3	—2·6	2·8	Not significant.
			(e) Seasonal malaria, non-malaria season.		
71–80 ..	33·8	34·8	—1·0	2·9	Not significant.
61–70 ..	35·1	37·7	—2·6	2·2	Not significant.
51–60 ..	41·3	35·4	+5·9	2·1	Not significant.
41–50 ..	43·5	31·0	+12·5	2·0	Significant.
31–40 ..	30·2	34·0	—3·8	2·1	Not significant.
21–30 ..	29·9	29·2	+0·7	2·4	Not significant.
11–20 ..	34·6	30·0	+4·6	2·4	Not significant.

Other points which may be noted in dealing with spleens of this size are the observations of Macdonald in Assam. He remarked that a positive blood was more frequently associated with spleens of this size than with smaller ones. He also noted that a moderate parasite count of between 100 and 1,000 parasites per c.mm. was predominantly associated with spleens of this size, and that they formed the most common size of spleen in children aged three to four, being less common in both younger and older children. In figure 11 it is noticeable that 6 and 7 cm. A-U spleens increase in frequency at spleen rates over 75 per cent.

4. *Spleens of 0 to 5 cm. A-U measurement.*—This group, as mentioned before, includes all spleens projecting beyond the umbilicus as well as those within 5 cm. They are in definite excess in seasonal malaria, malaria and non-malaria seasons (Tables IV*d* and IV*e*). There is also a single significant record of excess in epidemic malaria (Table IV*f*). They are in definite marked defect in static malaria (Table IV*a*), and show two or more significant records of defect in post-epidemic hyperendemicity, malaria and non-malaria seasons (Tables IV*b* and IV*c*), and epidemic malaria (Table IV*f*).

On account of the relative rarity of these spleens in static malaria the records from Assam are of little value. Many workers have noted the association of the largest spleens with a negative blood, for instance Macdonald and Majid (1931) noted that in one village repeatedly examined, only 2 out of 29, or 7 per cent, of children with spleens projecting to within 2 cm. of the umbilicus showed positive blood, the general parasite rate being 21 per cent. The marked increase in the frequency of these spleens at high spleen rates has already been noted.

TABLE IV.

The difference between the percentage frequency of 0–5 cm. A-U spleens in specified types of malaria from that in all other types.

Spleen rate.	Percentage of 0–5 cm. A-U spleens in this type of malaria.	Percentage of 0–5 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*a*) Static malaria.			
91–100 ..	17·0	29·1	—12·1	2·9	Significant.
81–90 ..	8·5	17·0	—8·5	1·8	Significant.
71–80 ..	12·3	13·4	—1·1	1·5	Not significant.
61–70 ..	7·1	11·4	—4·3	0·8	Significant.
51–60 ..	1·9	10·2	—8·3	2·0	Significant.
41–50 ..	0	10·0	—10·0	2·9	Significant.
31–40 ..	6·2	7·4	—1·2	0·9	Not significant.

TABLE IV—*contd.*

Spleen rate.	Percentage of 0–5 cm. A-U spleens in this type of malaria.	Percentage of 0–5 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*b*) Post-epidemic hyperendemicity, malaria season.			
91–100 ..	29·2	26·3	+2·9	2·8	Not significant.
81–90 ..	13·0	17·4	—4·4	1·4	Significant.
51–60 ..	7·0	9·3	—2·3	1·5	Not significant.
31–40 ..	0	7·8	—7·8	1·8	Significant.
		(*c*) Post-epidemic hyperendemicity, non-malaria season.			
91–100 ..	24·4	29·2	—4·8	2·3	Not significant.
81–90 ..	9·1	16·9	—7·8	2·4	Significant.
71–80 ..	13·8	13·1	+0·7	2·2	Not significant.
61–70 ..	8·3	11·8	—3·5	0·7	Significant.
51–60 ..	8·0	10·0	—2·0	1·3	Not significant.
41–50 ..	4·9	10·8	—5·9	1·4	Significant.
31–40 ..	8·9	6·8	+2·1	1·3	Not significant.
		(*d*) Seasonal malaria, malaria season.			
81–90 ..	21·6	15·5	+6·1	2·7	Not significant.
71–80 ..	20·5	10·9	+9·6	1·4	Significant.
61–70 ..	18·0	9·1	+8·9	1·0	Significant.
51–60 ..	14·8	8·9	+5·9	1·4	Significant.
41–50 ..	14·2	8·1	+6·1	1·2	Significant.
31–40 ..	3·8	7·4	—3·6	1·8	Not significant.
21–30 ..	5·8	7·0	—1·2	1·3	Not significant.
11–20 ..	8·5	7·7	+0·8	1·6	Not significant.
		(*e*) Seasonal malaria, non-malaria season.			
71–80 ..	15·8	12·9	+2·9	2·1	Not significant.
61–70 ..	19·0	9·9	+9·1	1·4	Significant.
51–60 ..	15·2	8·4	+6·8	1·3	Significant.
41–50 ..	14·9	7·8	+7·1	1·2	Significant.
31–40 ..	13·2	5·2	+8·0	1·2	Significant.
21–30 ..	8·1	5·2	+2·9	1·3	Not significant.
11–20 ..	8·3	7·3	+1·0	1·4	Not significant.

TABLE IV—*concld.*

Spleen rate.	Percentage of 0–5 cm. A-U spleens in this type of malaria.	Percentage of 0–5 cm. A-U spleens in all other types of malaria.	Difference between these percentages.	Probable error of difference.	Significance of difference.
		(*f*) Epidemic malaria.			
91–100 ..	36·1	25·5	+10·6	3·5	Significant.
81–90 ..	21·9	11·8	+10·1	1·4	Significant.
71–80 ..	8·5	16·2	—7·7	1·2	Significant.
61–70 ..	8·8	11·0	—2·2	1·0	Not significant.
51–60 ..	7·7	10·6	—2·9	1·1	Not significant.
41–50 ..	4·8	11·3	—6·5	1·2	Significant.
31–40 ..	3·5	7·9	—4·4	1·3	Significant.

Conclusions.

Taking all the facts detailed above into consideration, a theory of the causation of the various degrees of splenic enlargement may be formulated, and reasons for variations from the normal distribution curve distinguished.

The initial attack of malaria will normally, if it causes enlargement of the spleen, cause it to project to within 9, 10 or 11 cm. of the umbilicus, probably 10 cm. Hypertrophy beyond this stage is rare until the individual has been infected, and has had an enlarged spleen for a couple of years or more. The evidence on this is (1) the excess of this size of spleen in epidemic malaria, when the majority of the infections are new and when the spleen rate rapidly increases: (2) their excess in post-epidemic hyperendemicity, malaria season, when numerous fresh infections are still taking place; (3) the frequency of this size of spleen in children under three, when infection is inevitably fairly recent; (4) Covell and Baily's observation on its frequency in those recently exposed to severe infection. This degree of enlargement is possibly in many cases due to mere engorgement and rapidly subsides after the initial attack, or under the influence of treatment, as has been pointed out by Sinton (1927). Their disappearance produces the seasonal variations in the spleen rate noted by Iyengar and Sur (1929) and Macdonald and Majid (1931).

When infection, and enlargement of the spleen, has become firmly established, the temporary engorgement becomes replaced by a definite hypertrophy, the size of the spleen, however, remaining much the same, and projecting to within 10 cm. of the umbilicus. While infection is quiescent the spleen remains

of this size. The evidence on which this statement is based is (1) the age distribution of these spleens in Assam, where it constituted the modal size for children aged six to ten, who are partially immune, as well as those aged under three; (2) its association with low parasite rates and low parasite counts in the hyperendemic areas in Assam, indicating its association with immunity and quiescence; (3) the decrease in the relative frequency of these spleens at spleen rates over 75 per cent, when re-infections must be common and quiescent infections more rare than at lower spleen rates.

Once a spleen has become hypertrophied in this manner, re-infection or relapse is accompanied by a further increase in size, so that it projects to within 8 cm. of the umbilicus. The difference of 2 to 3 cm. in length between the spleens of chronic quiescent and chronic active malaria explains the bimodal character of the frequency polygons. The evidence on this point is: (1) Macdonald's observation in Assam that spleens of this size were more commonly associated with a positive blood than smaller ones, and that they were predominantly associated with a moderate parasite count of from 100 to 1,000 parasites per c.mm., such as might be expected in a person who had a long standing infection, and had consequently acquired a certain degree of immunity; (2) the relative frequency of these spleens in children aged three to four in Assam. Children of this age, living in a hyperendemic area, have been infected for some time but are still liable to re-infection and relapse; (3) Macdonald and Majid examined a number of children at monthly intervals for a long period, and noted that re-infection of the peripheral blood was commonly associated with further enlargement of the spleen; (4) Sinton's observations on soldiers. He noted that there were two types of enlarged spleen amongst them, acutely engorged, and chronically hypertrophied, and remarked that 'the spleens with old enlargements are also liable to superimposed acute enlargement due to an acute attack of the disease supervening on the chronic infection'; (5) the relative frequency of spleens of this size in seasonal malaria, and post-epidemic hyperendemicity, non-malaria season, when the great majority of infections are relapses in persons chronically infected, and when fresh infections are non-existent. There is in the malaria season an actual further increase in the number of these spleens, as may be seen by reference to Table XI of Macdonald and Majid's paper, but it is commonly obscured by the associated increase in the spleen rate. This explains their relative defect in seasonal malaria and post-epidemic hyperendemicity, malaria season; (6) their increased relative frequency at high spleen rates, shown in figure 11, when overlapping of infections is most common.

Very large spleens, projecting to within 5 cm. or less of the umbilicus, are an indication of frequent re-infection in those who have had enlargement of the spleen for some years, but have not yet acquired any marked degree of immunity. The largest spleens, projecting to within 2 cm. or less of the

umbilicus, may be associated with the development of a certain degree of immunity. It is highly probable that in areas of static endemicity, with a normal long transmission period, the frequency of re-infection with malaria is less than in seasonal malaria, malaria season, where the period of transmission is short. Macdonald (1931) gave some reasons for believing the inoculation rate to be low in areas of static endemicity, although the spleen rate might be very high. In areas of mild seasonal malaria, however, the increase in the spleen and parasite rates at the commencement of the malaria season is normally quite rapid, evidencing a high inoculation rate. This difference may be ascribed to the more generally acquired immunity in the former areas, and the decreased prevalence of gametocytes. The following evidence in favour of this explanation of the reason for this degree of splenic enlargement may be cited. (1) Their deficiency in static malaria, where re-infections are less frequent and immunity more firmly established than in seasonal malaria; (2) their deficiency in epidemic malaria, where infections are for the most part recent, only a small portion of the population affected having previously suffered from enlargement of the spleen; the same explanation applies to their deficiency in post-epidemic hyperendemicity; (3) their excess in seasonal malaria, where re-infection may be very frequent and a considerable proportion of the affected population has previously suffered from enlargement of the spleen; (4) their excess at high spleen rates (figure 11) where frequent re-infection is most common.

Mild infections with malaria, which may be due to the prevailing mildness of the disease, or to the development of a considerable degree of immunity in the population affected, are associated with the development of spleens projecting to within 12 to 15 cm. of the umbilicus. The evidence on this point is:—(1) their frequency at low spleen rates; (2) their marked excess in static malaria, where a considerable degree of immunity is commonly developed. In cases of post-epidemic hyperendemicity, where the spleen rate is high, the same explanation also applies; (3) their defect in seasonal malaria and in epidemic malaria, where infection is normally severe and immunity less firmly established. In cases of post-epidemic hyperendemicity, with low spleen rates, the same explanation probably also applies, as the epidemic has probably been less severe than in areas with a high spleen rate; (4) Macdonald's Assam record of the relatively low parasite rate associated with this size of spleen; (5) their general temporary character.

The result of value to the field worker which may be drawn from this analysis is that the percentage frequency of each grade of splenic enlargement found in a malaria survey may be compared with that given in Table A in the appendix, for the same spleen rate, and useful deductions made as to the type of malaria in the area under survey. It will be noted that the reliance to be placed on an excess or deficiency of any one grade of enlargement is not very

great. It is, however, hoped that by a careful comparison of the whole spleen composition with the normal some conclusions of value may be forthcoming.

An excess of 12–15 cm. A-U spleens discovered in a survey would imply that the malaria was unduly mild, and this would normally be due to the development of a considerable degree of immunity in the population. If it were due to the prevailing mildness of infection, without considerable immunity, it would be represented by a low spleen rate. A deficiency of spleens of this size would imply that there was a relative lack of immunity, and that the severity of malaria was unstable.

An excess of 9–11 cm. A-U spleens would indicate that fresh infections were occurring amongst those previously without enlargement of the spleen. It would normally be associated with a recent considerable increase in the amount of malaria fever, and an increase in the spleen rate. A deficiency of spleens of this size is not so easily interpreted, owing to concomitant changes in the spleen rate, and should be examined along with the changes in the percentage frequency of other grades of enlargement.

Excess of 6–8 cm A-U spleens implies that a considerable number of relapses or re-infections are occurring in persons who have previously had enlargement of the spleen, and that they are in excess of the number of new infections taking place in those previously without splenic enlargement. It would usually imply that the observation had been made during the non-malaria season. after a decrease in the amount of malaria fever, and a decrease in the spleen rate. A deficiency of spleens of this size would mean that relapses and re-infections were relatively less frequent than new infections.

Spleens projecting to within 5 cm. or less of the umbilicus, when in excess of the normal, are an indication that the severity of malaria has not altered greatly in recent years, that the inoculation rate during the malaria season is high, and immunity is not well established in the population. A deficiency of these spleens denotes that either there has been a considerable recent increase in the severity of malaria, and the majority of the infections are of short standing, or that majority of infections are mild, probably due to the development of a high degree of immunity in the population.

Summary.

The history of the evolution of methods of measurement of enlarged spleens is briefly discussed, and Christophers and Khazan Chand's method described.

Records of the measurements of 12,695 enlarged spleens are available for analysis. They include examples of all types of malaria, taken at all times of year.

The records are classified (1) according to the spleen rate of the village or other unit in which they were taken, ten grades of spleen rate being used,

and (2) according to the prevailing type of malaria. The classification of malaria used for this purpose was (1) *Static malaria*, (2) *Seasonal malaria*, (*a*) *malaria season* and (*b*) *non-malaria season*, (3) *Epidemic malaria*, and (4) *Post-epidemic hyperendemicity*, (*a*) *malaria season* and (*b*) *non-malaria season*.

From the combined results of all types of malaria frequency tables and polygons for each grade of spleen rate, and figures showing the variations in the frequency of each size of spleen with varying spleen rates have been prepared, and their characteristics noted.

The records of measurements are then grouped into four groups according to whether the apex-umbilicus measurement fell between (1) 12 and 15 cm., (2) 9 and 11 cm., (3) 6 and 8 cm. or (4) 0 and 5 cm. Each of these groups is then taken *seriatim*, and the proportion of enlarged spleens falling into it, in each type of malaria, compared with that in all other types of malaria combined. This has been done for each of the ten grades of spleen rate for which sufficient figures are available. The probable error and the significance of the results are shown. Any available relevant evidence on the aetiology of each size of spleen is also noted.

From the evidence thus gathered together a theory of the causation of the various degrees of splenic enlargement is formulated. Briefly this is that the initial attack of malaria causes a relatively small enlargement of the spleen, possibly due to temporary engorgement only. When an individual has suffered for a couple of years or more from splenic enlargement a definite hypertrophy takes place, though the size of the spleen remains unaltered. A re-infection or a relapse in an individual with a spleen of this type results in further enlargement. Spleens projecting to within approximately 10 cm. of the umbilicus represent, therefore, either a recent active infection, or a chronic quiescent infection. Spleens projecting to within 6 or 8 cm. of the umbilicus represent re-infections or relapses in those long infected. Larger spleens are due to frequent re-infection in an individual who has for some years suffered from splenic enlargement, but in whom immunity is not yet well developed. Very small spleens are due to a mild attack of malaria; the mildness of the attack is very frequently due to a partial immunity in the individual infected. An excess of spleens of this type connotes that the amount of malaria prevalent is static, and immunity well developed.

The deductions which may be drawn from an examination of the measurements of enlarged spleens made during a malaria survey are discussed.

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APPENDIX.

Table A.

The percentage frequencies of all sizes of spleens, at different spleen rates, for all types of malaria combined.

A·U measurement.	Percentage of all enlarged spleens, at spleen rates of									
	91–100	81–90	71–80	61–70	51–60	41–50	31–40	21–30	11–20	1–10
15 cm. ..	0·0	0·1	0·5	0·9	0·6	0·1	5·0	1·3	2·5	0·0
14 „ ..	0·1	0 8	0·7	0·9	0·8	1·0	1·1	0·6	1·6	0·0
13 „ ..	1·0	1·7	3·1	2·5	3·8	3·4	3·5	4·1	4·0	4·1
12 „ ..	2·2	6·0	6·0	5·7	6·7	6·8	7·4	12·6	6·7	8·3
11 „ ..	5·8	7·4	10·5	9·9	9·7	10·2	11·0	14·1	12·0	13·2
10 „ ..	11·6	15·6	17·5	17·7	18·0	20·6	17·8	19·0	18·0	20·6
9 „ ..	10·0	10 9	13·8	14 5	14·4	13·9	14·0	12·2	14·7	13·2
8 „ ..	14·3	16·8	15·9	16·4	17·2	15·0	15·6	13·7	14·2	12·4
7 „ ..	15·1	14·5	10·9	11·4	11·7	11·7	11·8	8·9	10·3	12·4
6 „ ..	13·0	10·4	7·8	9·7	7·5	7·7	5·7	7·0	8·2	9·9
5 „ ..	9·9	4·6	5·6	4·2	3·8	3·6	3·4	2·8	3·7	0·8
4 „ ..	6·4	4·3	3·6	3·5	2·8	2·6	1·7	2·0	2·6	2·5
3 „ ..	4·1	2·2	1·9	1·3	1·4	1·8	1·1	0·7	0·7	1·7
2 „ ..	1·1	1·0	0·5	0·3	0·4	0·4	0·3	0·3	0·3	0·0
1 „ ..	1·5	0·8	0·4	0·2	0·3	0·4	0·1	0·1	0·1	0·0
0* „ ..	3·9	2·9	1·4	0·9	0·9	0·8	0·5	0·6	0·4	1·7
Number examined.	709	1,709	1,984	5,096	2,950	3,078	3,454	2,677	4,359	1,999
Number positive.	668	1,457	1,482	3,356	1,624	1,366	1,251	687	683	121
Spleen rate	94·2	85·3	74·7	65·8	55·0	44·4	36·2	25·7	15·7	6·1

* This figure includes all those spleens projecting beyond the umbilicus as well as those reaching to it.

TABLE B.

The percentage frequencies of all sizes of spleens, at different spleen rates, in static malaria.

A-U measurement.	Percentage of all enlarged spleens, at spleen rates of									
	91–100	81–90	71–80	61–70	51–60	41–50	31–40	21–30	11–20†	1–10†
15 cm. ..	0·0	0·0	0·3	4·2	2·8	0·0	16·9	2·3	..	..
14 „ ..	0·8	2·0	1·0	1·8	0·0	5·9	0·3	0·0	..	..
13 „ ..	1·5	1·0	4·0	2·3	20·7	5·9	2·9	9·1	..	..
12 „ ..	4·7	11·6	6·0	6·7	12·3	7·8	6·2	18·2	..	..
11 „ ..	5·4	8·5	11·1	12·2	10·4	19·6	9·4	13·7	..	..
10 „ ..	15·5	18·1	16·1	19·8	13·2	25·5	10·7	22·7	..	..
9 „ ..	10·1	9·5	13·8	16·5	11·4	13·7	13·6	6·8	..	..
8 „ ..	17·8	13·1	14·1	13·4	10·4	13·7	15·3	4·5	..	..
7 „ ..	14·0	16·0	12·1	9·1	8·5	7·8	12·0	13·6	..	..
6 „ ..	13·2	11·7	9·1	6·8	8·5	0·0	6·5	9·1	..	..
5 „ ..	7·8	4·0	5·0	2·6	0·9	0·0	3·9	0·0	..	..
4 „ ..	3·1	2·0	3·7	2·3	0·9	0·0	1·0	0·0	..	..
3 „ ..	1·6	1·0	2·0	0·9	0·0	0·0	1·0	0·0	..	..
2 „ ..	1·6	0·5	0·0	0·0	0·0	0·0	0·0	0·0	..	..
1 „ ..	1·6	0·0	0·7	0·2	0·0	0·0	0·0	0·0	..	..
0* „ ..	1·6	1·0	1·0	1·2	0·0	0·0	0·3	0·0	..	..
Number examined.	138	242	412	979	193	105	774	179	134	88
Number positive.	129	199	298	661	106	51	308	44	24	8
Spleen rate..	93·5	82·2	72·3	67·5	54·9	48·6	39·8	24·6	17·9	9·1

* This figure includes all those spleens projecting beyond the umbilicus, as well as those just reaching to it.

† Frequencies not given, the number of children with enlarged spleens being too small to give reliable results.

TABLE C.

The percentage frequencies of all sizes of spleens, at different spleen rates, in post-epidemic hyperendemicity, malaria season.

A-U measurement.	Percentage of all enlarged spleens, at spleen rates of			
	91–100	81–90	51–60	31–40
15 cm. ..	0·0	0·4	0·5	0·0
14 „ ..	0·0	1·2	1·1	1·0
13 „ ..	0·0	3·0	3·8	7·8
12 „ ..	0·0	6·5	7·0	7·8
11 „ ..	5·0	8·3	14·5	12·6
10 „ ..	12·5	16·4	19·9	26·2
9 „ ..	11·7	10·5	15·6	14·6
8 „ ..	10·8	15·6	14·5	11·6
7 „ ..	15·8	15·2	9·7	15·5
6 „ ..	15·0	10·1	6·5	2·9
5 „ ..	10·8	3·9	0·5	0 0
4 „ ..	9·2	3·9	2·7	0·0
3 „ ..	2·5	1·6	3·2	0·0
2 „ ..	2·5	1·2	0·5	0·0
1 „ ..	1·7	0·8	0·0	0·0
0* „ ..	2·5	1·6	0·0	0·0
Number examined	124	582	320	333
Number positive	120	507	186	103
Spleen rate ..	96·8	87·1	58·1	30·9†

* This figure includes all those spleens projecting beyond the umbilicus as well as those just reaching to it.

† In classifying the villages according to spleen rates, these were taken to the *nearest whole figure*, hence the appearance of the figure 30·9 per cent in the 31 to 40 per cent group.

TABLE D.

The percentage frequencies of all sizes of spleens, at different spleen rates, in post-epidemic hyperendemicity, non-malaria season.

A-U measurement.	Percentage of all enlarged spleens, at spleen rates of							
	91–100	81–90	71–80	61–70	51–60	41–50	31–40	11–20
15 cm.	0·0	0·0	0·0	0·1	0·3	0·0	0·0	0·0
14 „	0·0	0·0	0·0	0·7	0·3	0·4	0·5	2·1
13 „	1·2	2·0	2·6	3·6	3·0	4·9	2·3	4·2
12 „	1·8	7·1	4·3	7·3	5·0	9·1	6·5	0·0
11 „	7·1	9·1	4·3	10·3	8·0	12·2	8·4	22·9
10 „	9·5	18·8	13·8	16·8	20·3	21·3	24·3	22·9
9 „	9·8	10·7	15 5	14·2	12·0	13·3	13·5	12·5
8 „	14·0	19 8	17·2	17·1	20·7	18 2	17·8	14·6
7 „	16·4	12·2	16·4	11·0	14·3	9·5	12·2	10·4
6 „	12·8	11·2	12·1	10·6	8·0	6·1	5·6	2·1
5 „	9·2	3·1	0·9	2·8	3·3	2·7	2·3	4·2
4 „	6·0	2·0	3 4	3·4	2·0	0·8	2·8	2·1
3 „	5·6	2·0	6·0	1·2	1·3	1·5	1·9	0·0
2 „	0·6	0·5	2·6	0·2	0·7	0·0	0·5	0·0
1 „	1·5	0·5	0·0	0·2	0·0	0·0	0·5	0·0
0* „	4·5	1·0	0·9	0·5	0·7	0·0	0·9	2·1
Number examined ..	356	229	147	1,855	554	579	580	245
Number positive ..	336	197	116	1,224	300	263	214	48
Spleen rate ..	94·4	86·0	78·9	66·0	54·2	45·4	36·9	19·6

* This figure includes all those spleens projecting beyond the umbilicus as well as those just reaching to it.

TABLE E.

The percentage frequencies of all sizes of spleens, at different spleen rates, in seasonal malaria, malaria season.

A-U measurement.	Percentage of all enlarged spleens, at spleen rates of								
	81–90	71–80	61–70	51–60	41–50	31–40	21–30	11–20	1–10
15 cm. ..	0·0	0·3	0·0	0·0	0·0	0·0	1·6	1·7	0·0
14 " ..	1·1	1·2	0·5	2·2	0·3	0·0	0·8	1·7	0·0
13 " ..	2·3	2·3	1·5	3·6	4·4	8·7	3·5	5·1	0·0
12 " ..	2 3	4·9	4·0	12·6	7·0	7·7	16·0	5·1	7·1
11 " ..	8·0	8·1	6·8	9·4	11·0	15·4	17·9	13·6	7·1
10 " ..	13·6	14·7	16·6	14·3	21·5	23·1	14·4	17·6	21·4
9 " ..	13·6	10·7	13·2	13 5	11·9	11·6	12·1	15·9	21·4
8 " ..	15·9	17 4	16·4	11·7	10·5	16·3	13·2	12·0	17·9
7 " ..	11·4	10·4	11·0	10·8	11·4	6·7	7·4	9·7	3·6
6 " ..	12·5	9·5	12·1	7·2	7·8	6·7	7·4	9·1	17·9
5 " ..	4·5	9·2	7·3	8·1	5·2	0·0	3·1	2·3	0·0
4 " ..	6·8	5·8	6·2	3·6	3·2	1·9	1·2	4·0	0·0
3 , ..	1·1	1·2	2·2	1·3	3·2	1·0	0·8	1·1	3·6
2 " ..	4·5	0·6	0·7	0·4	0·6	1·0	0·4	1·1	0·0
1 " ..	2·3	0·3	0·2	0·9	0·9	0·0	0·0	0·0	0·0
0* " ..	2·3	3·5	1·3	0·4	1·2	0·0	0·4	0·0	0·0
Number examined	100	456	836	401	772	284	1,019	1,196	318
Number positive ..	88	346	545	223	344	104	257	176	28
Spleen rate ..	88	75·8	65·2	55·6	44·6	36·6	25·2	14·7	8·8

* This figure includes all those spleens projecting beyond the umbilicus as well as those just reaching to it.

TABLE F.

The percentage frequencies of all sizes of spleens, at different spleen rates, in seasonal malaria, non-malaria season.

A-U measurement.	Percentage of all enlarged spleens, at spleen rates of							
	71–80	61–70	51–60	41–50	31–40	21–30	11–20	1–10
15 cm.	0·0	0·4	0·7	0·0	2·7	1·2	3·5	0·0
14 "	0·7	0·4	0·3	1·7	2·4	0·3	1·8	0·0
13 "	2·3	3·3	1·6	1·4	2·7	4·4	3·5	0·0
12 "	6·0	4·1	4·9	3·9	8·8	10·3	7·6	11·8
11 "	8·3	11·2	8·3	7·3	10·8	10·9	9·1	15·7
10 "	16·6	12·0	17·2	14·9	14·6	22·5	16·9	17·6
9 "	16·6	14·5	10·5	12·4	14·6	12·5	14·6	13·7
8 "	12·8	14·0	17·5	17·2	15·2	14·4	14·6	11·8
7 "	9·8	10·8	13·9	12·6	10·2	9·7	11·1	13·7
6 "	11·3	10·3	9·9	13·8	4·7	5·9	8·8	9·8
5 "	9·0	9·9	5·0	5·3	6·8	2·8	4·6	2·0
4 "	3·0	4·6	5·0	4·2	3·1	2·8	2·3	2·0
3 "	0·7	0·8	1·6	2·0	1·7	0·9	0·8	2·0
2 "	0·7	0·8	0·3	1·1	0·7	0·3	0·0	0·0
1 "	1·5	0·4	0·3	0·6	0·0	0·3	0·3	0·0
0* "	0·7	2·5	3·0	1·7	1·0	0·9	0·5	0·0
Number examined ..	183	369	561	821	826	1,246	2,453	1,065
Number positive ..	133	242	303	356	295	321	396	51
Spleen rate ..	72·7	65·6	54·0	43·4	35·7	25·8	16·1	4·8

* This figure includes all those spleens projecting beyond the umbilicus as well as those just reaching to it.

TABLE G.

The percentage frequencies of all sizes of spleens, at different spleen rates, in epidemic malaria.

A-U measurement.	Percentage of all enlarged spleens, at spleen rates of									
	91–100	81–90	71–80	61–70	51–60	41–50	31–40	21–30	11–20	1–10
15 cm. ..	0·0	0·0	0·8	0·1	0·4	0·6	0·9	0·0	0·0	0·0
14 „ ..	0·0	0·2	0·3	0·7	0·6	0·6	1·8	1·5	0·0	0·0
13 „ ..	1·2	0·6	3·4	1·5	2·2	2·8	2·2	1·5	0·0	11·8
12 „ ..	3·6	3·2	7·0	3·7	4·7	7·7	7·9	6·2	12·8	2·9
11 „ ..	2·4	6·2	13·4	9·2	9·9	9·7	13·3	15·4	20·5	14·7
10 „ ..	12·0	13·8	20·9	19·5	18·8	24·7	19·0	18·5	23·1	23·5
9 „ ..	8·4	11·6	14·8	14·2	18·8	17·6	15·0	15·4	15·3	5·9
8 „ ..	14·5	18·9	16·5	18·7	20·2	14·8	15·9	18·5	18·0	5·9
7 „ ..	10·8	13·7	10·0	15·1	10·7	13·1	14·1	7·7	7·7	20·6
6 „ ..	10·8	9·9	4·6	8·6	6·1	3·7	6·6	9·2	2·6	5·9
5 „ ..	14·5	4·7	3·2	3·8	3·2	1·4	2·7	3·1	0·0	0·0
4 „ ..	9·6	6·7	2·5	2·5	2·4	2·3	0·4	3·1	0·0	5·9
3 „ ..	3·6	2·6	1·7	1·5	0·8	0·9	0·4	0·0	0·0	0·0
2 „ ..	0·0	1·3	0·2	0·1	0·4	0·0	0·0	0·0	0·0	0·0
1 „ ..	1·2	0·6	0·2	0·4	0·4	0·0	0·0	0·0	0·0	0·0
0* „ ..	7·2	6·0	0·7	0·4	0·6	0·3	0·0	0·0	0·0	0·0
Number examined.	91	556	786	1,057	921	801	657	233	331	528
Number positive.	83	466	589	684	506	352	227	65	39	34
Spleen rate..	91·2	88·0	74·9	61·8	54·9	43·9	34·5	27·9	11·8	6·4

* This figure includes all those spleens projecting beyond the umbilicus as well as those just reaching to it.

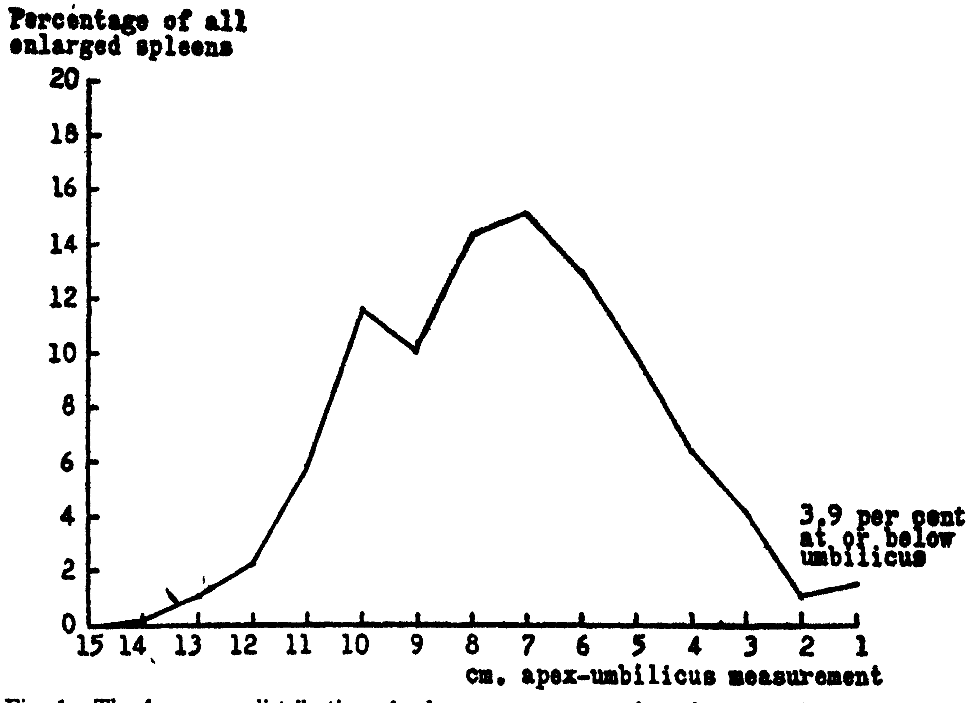


Fig. 1.—The frequency distribution of spleen measurements, for spleen rates between 91 and 100 per cent, in all types of malaria combined.

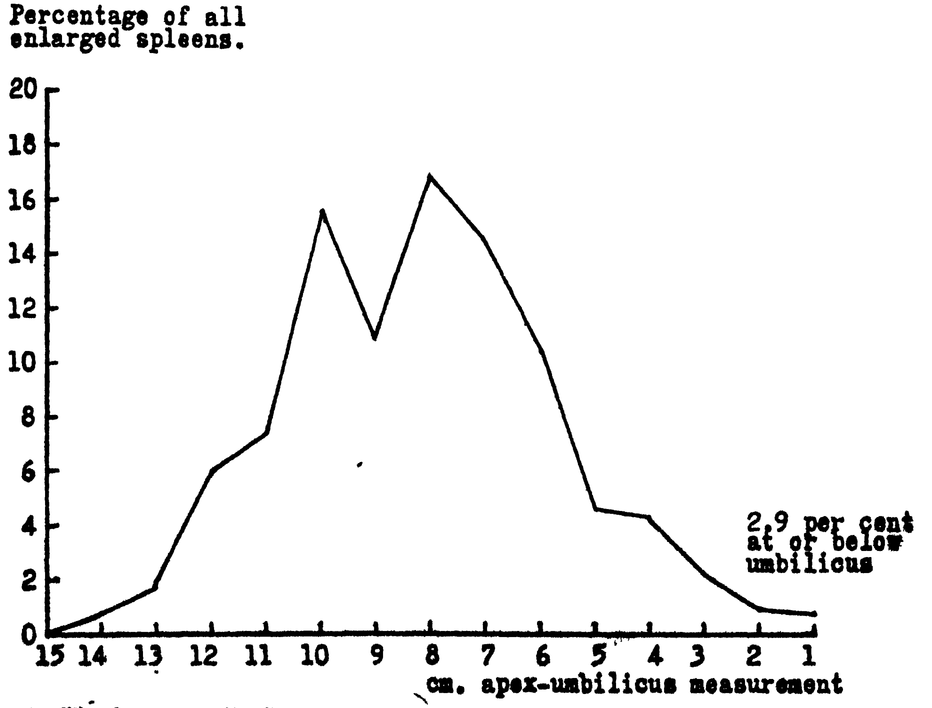


Fig. 2.—The frequency distribution of spleen measurements, for spleen rates between 81 and 90 per cent, in all types of malaria combined.

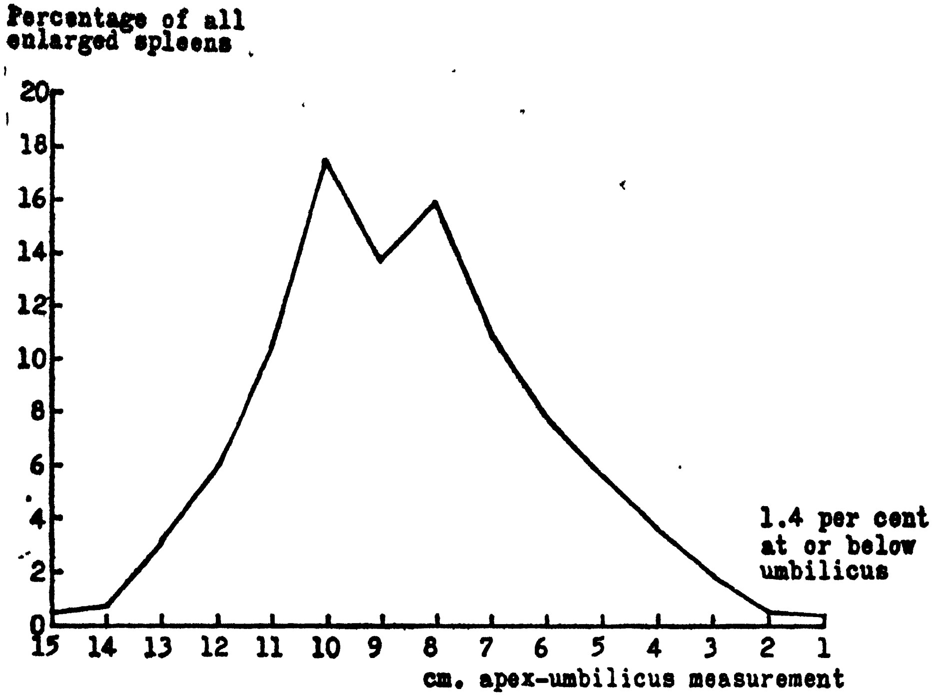


Fig. 3.—The frequency distribution of spleen measurements, for spleen rates between 71 and 80 per cent, in all types of malaria combined.

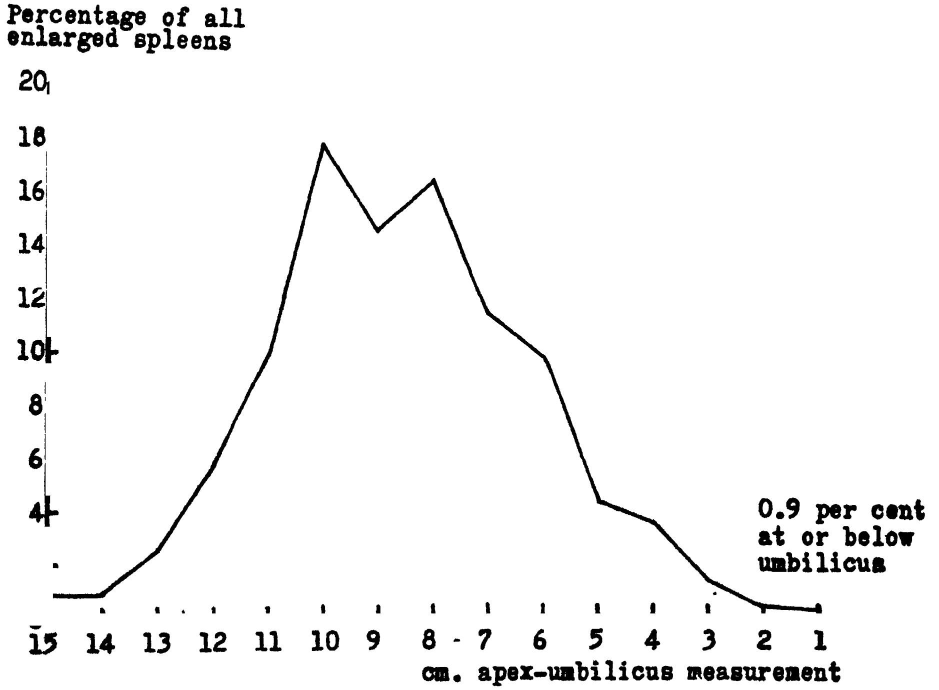


Fig. 4.—The frequency distribution of spleen measurements, for spleen rates between 61 and 70 per cent, in all types of malaria combined.

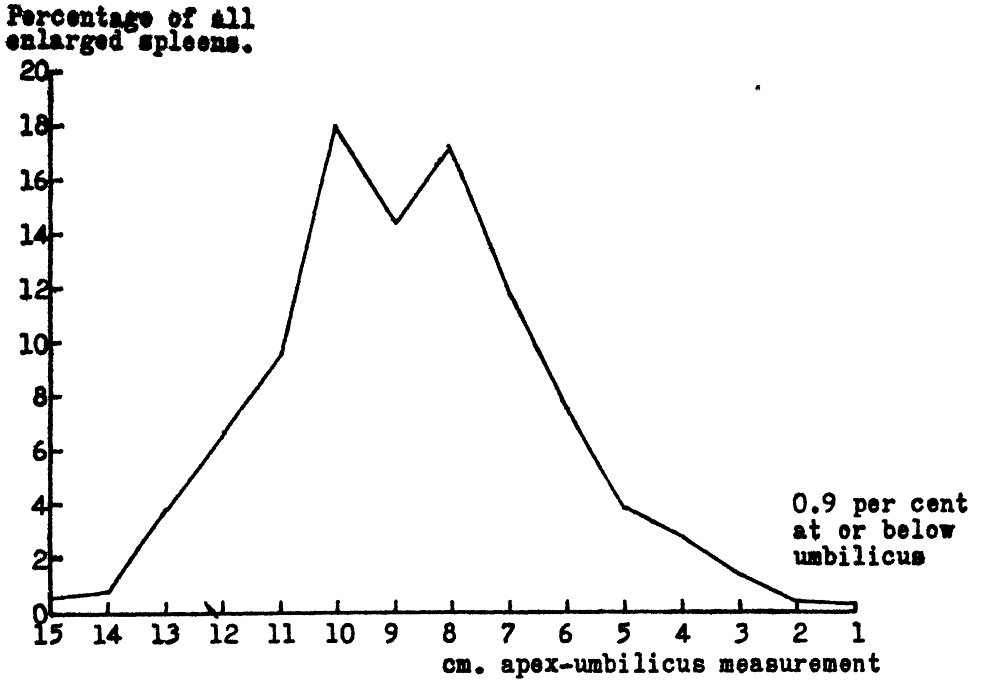


Fig. 5.—The frequency distribution of spleen measurements, for spleen rates between 51 and 60 per cent, in all types of malaria combined.

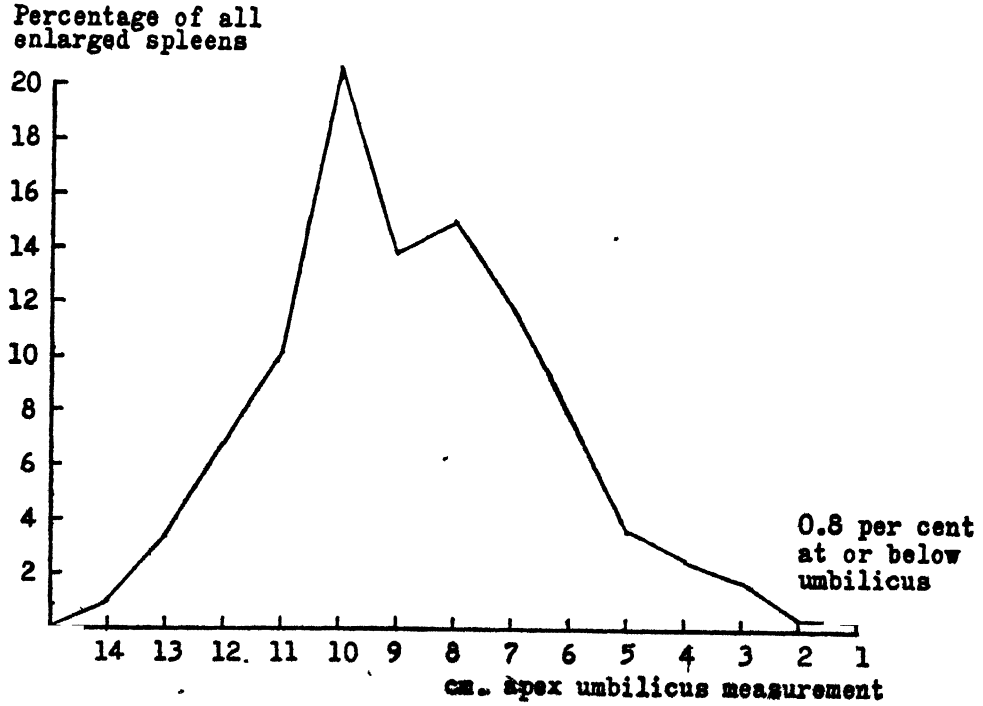


Fig. 6.—The frequency distribution of spleen measurements, for spleen rates between 41 and 50 per cent, in all types of malaria combined.

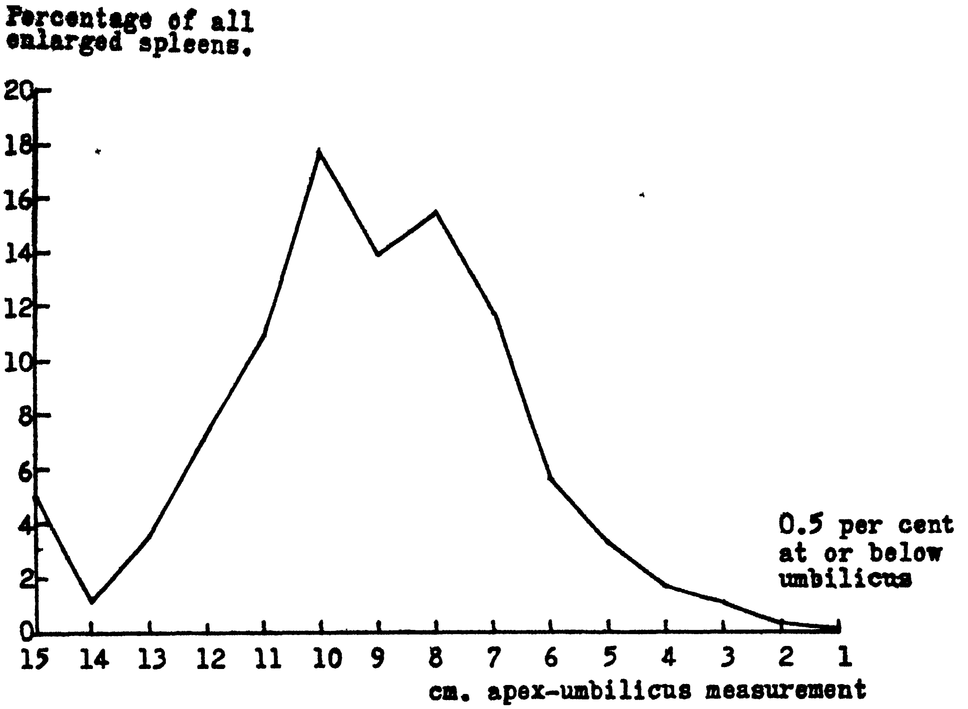


Fig. 7.—The frequency distribution of spleen measurements, for spleen rates between 31 and 40 per cent, in all types of malaria combined.

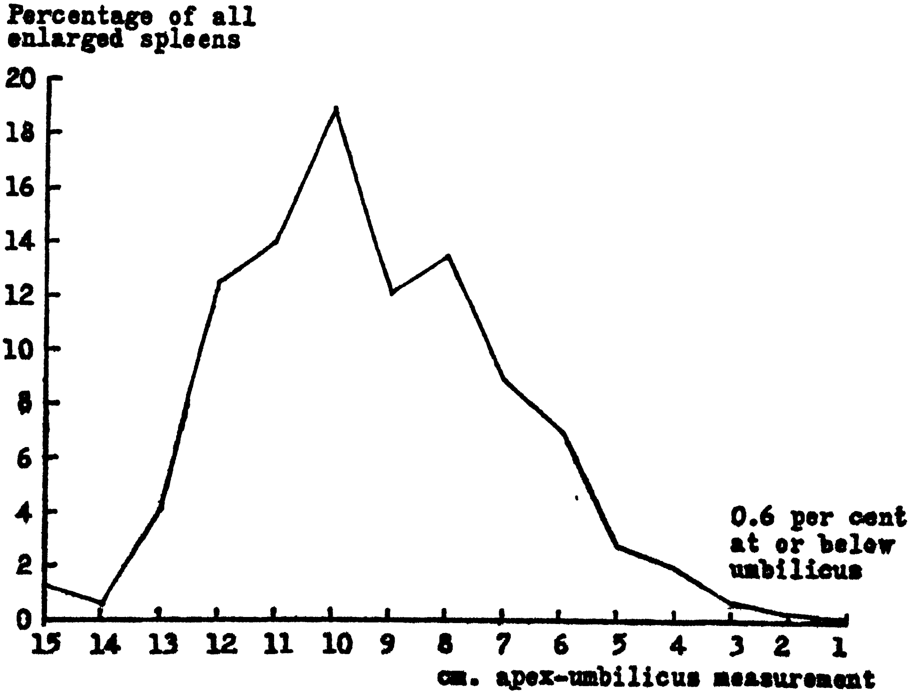


Fig. 8.—The frequency distribution of spleen measurements, for spleen rates between 21 and 30 per cent, in all types of malaria combined.

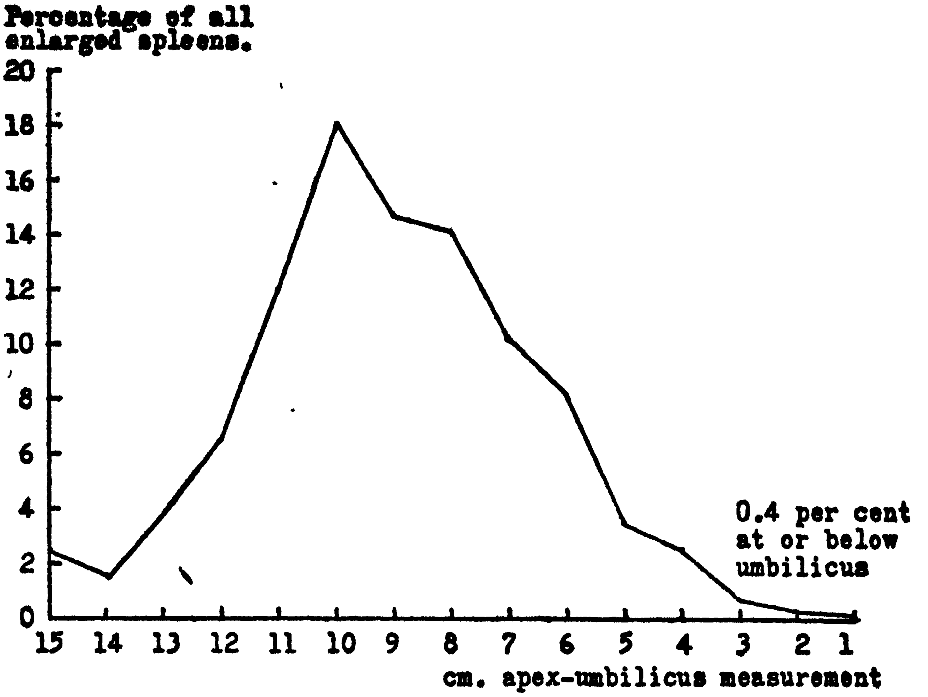


Fig. 9.—The frequency distribution of spleen measurements, for spleen rates between 11 and 20 per cent, in all types of malaria combined.

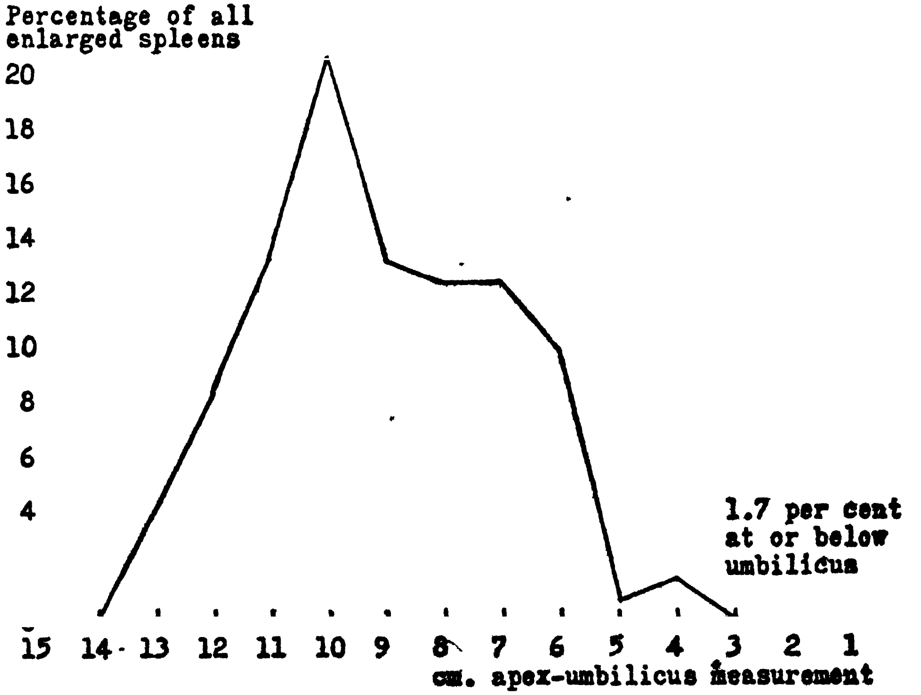


Fig. 10.—The frequency distribution of spleen measurements, for spleen rates between 1 and 10 per cent, for all types of malaria combined.

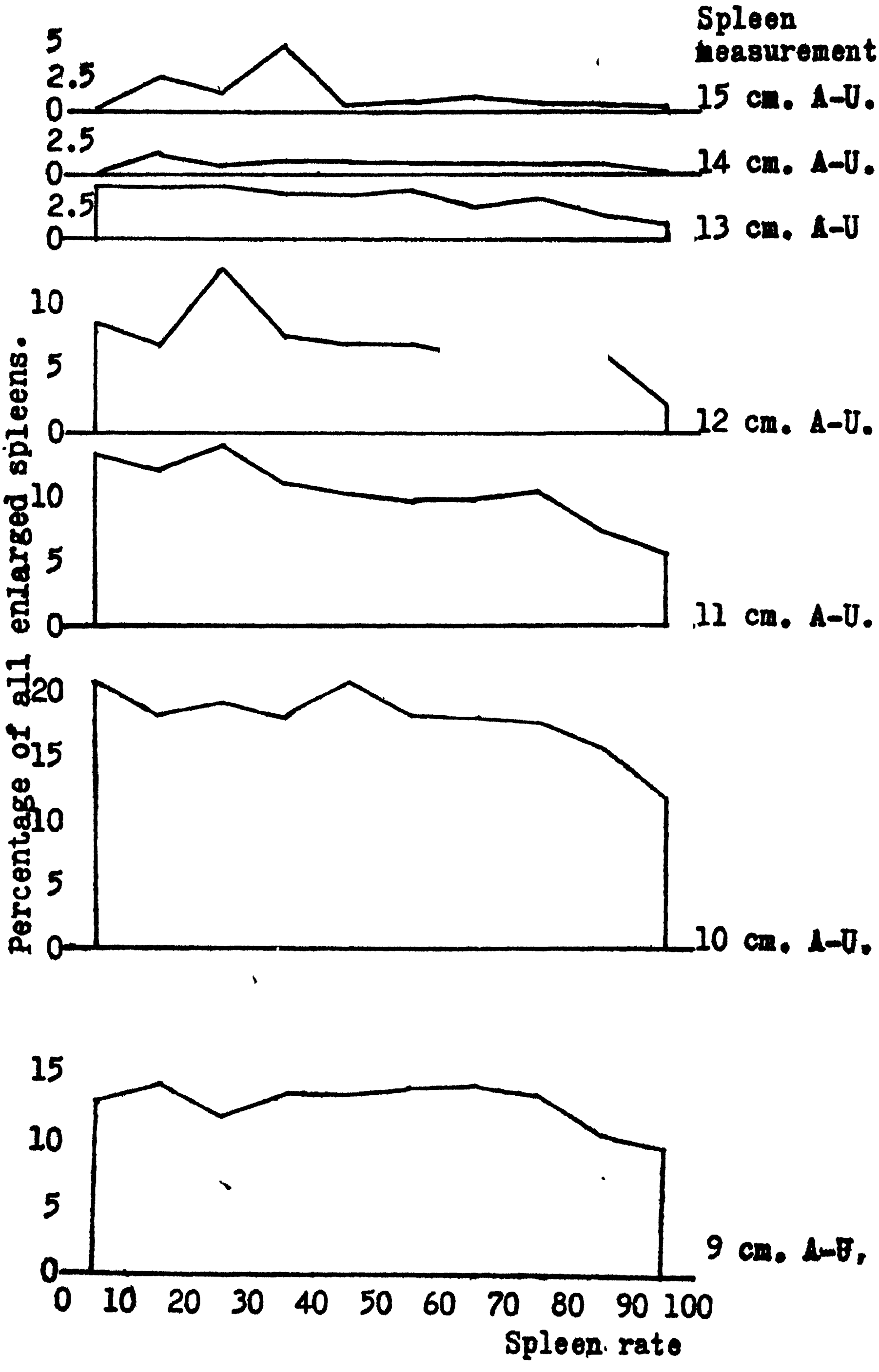


Fig. 11.—Variations in the frequency of spleens of specified size at different spleen rates.

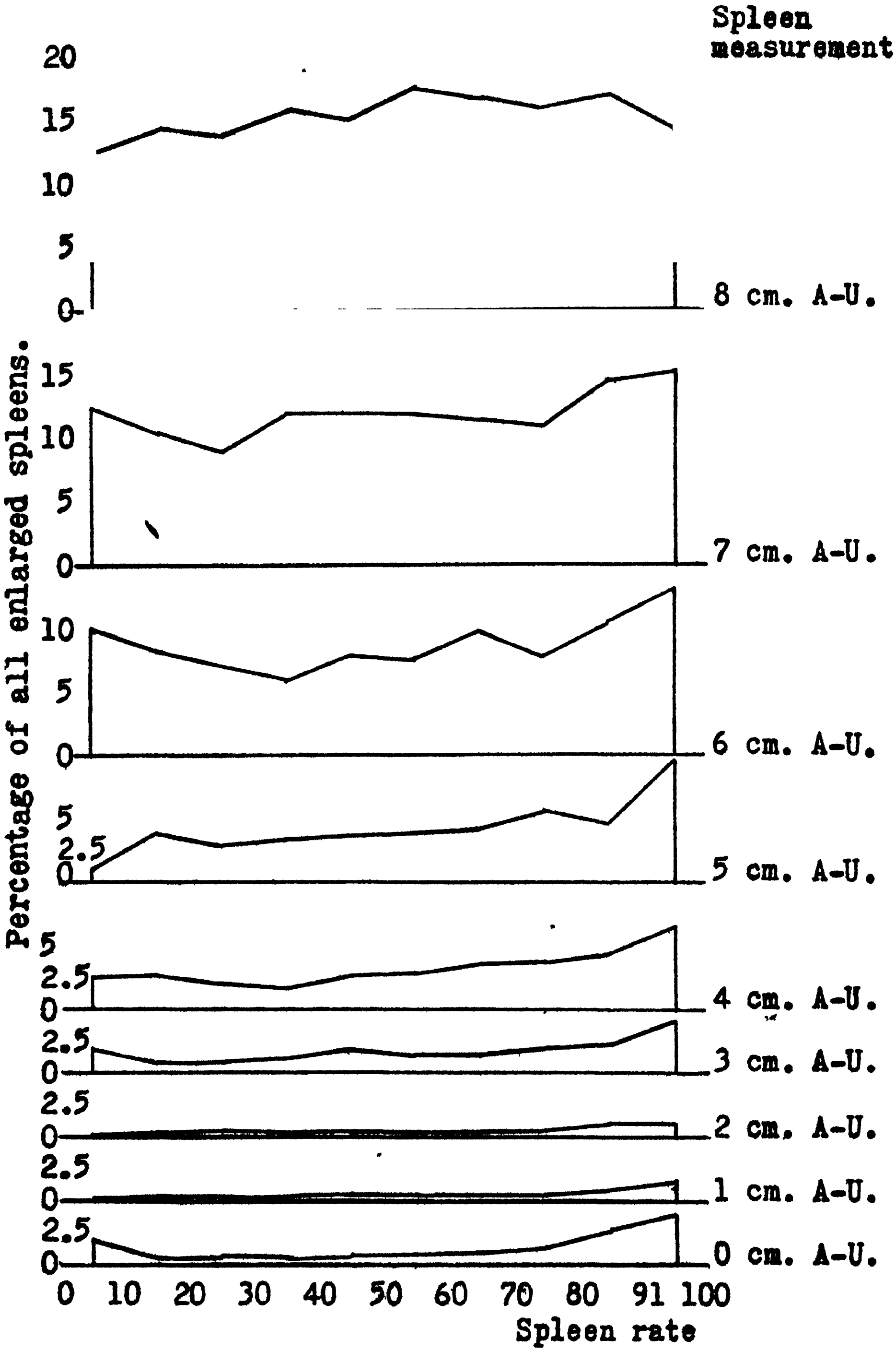


Fig. 11 (*concld.*).—Variations in the frequency of spleens of specified size at different spleen rates.

Records of the Malaria Survey of India, Vol. II, No. 4, December, 1931.

REPORT ON A MALARIA SURVEY IN BIKANER STATE.

BY

G. MACDONALD,

Malaria Research Officer, Malaria Survey of India.

[August 7, 1931.]

CONTENTS.

INTRODUCTION.

Bikaner City, with a population of some 95,000 persons, lies in latitude 28° North and longitude 73° East, and is the capital of Bikaner State, the northernmost State in Rajputana. Lallgarh and Bijhey Bhawan, the palaces of H. H. the Maharaja and his eldest son, are about a mile and a half away from the city. Some twenty miles from the capital is Gajner, a small village

of 200 houses, near which are three small palaces, an artificial lake, and a very large garden. At the request of the Bikaner Government I was deputed to make a malaria survey of the city and the palaces. I arrived in Bikaner for that purpose on July 19, 1931, and departed on July 29.

The surrounding country is extremely dry. The soil is mainly sand, with occasional outcrops of limestone and clay as at Gajner. During the dry season it is said to present the appearance of a vast undulating desert, and, indeed, it borders on the Great Indian Desert, but after good rain the appearance of the country is completely changed, grasses spring up in the desert, and a few crops are grown. Most of the rain sinks immediately into the ground, but where the configuration of the country permits it accumulates for a short time in natural hollows. Near towns and villages these accumulations of water are encouraged by deepening the natural hollows and construction bunds. The lake at Gajner has been enlarged in this way, and in the vicinity of Bikaner town there are a great many of these tanks. Some are purely natural, others have been enlarged by bunds, while the best have been completely stone lined and made into good bathing and washing places.

Drinking water is drawn from deep wells, the water level in which varies from 350 to 385 feet below ground level. The supply for the palaces and the officers' quarters is drawn by electric pumps and distributed in pipes. The city water is drawn by the 'charsa' system, bullocks lifting the water in a leathern bag to the well top, where it is tipped out into an open stone reservoir. It is then removed from these reservoirs in buckets. On account of the great cost of constructing one of these wells, and the labour involved in lifting water 350 feet to the surface, water is an expensive article, and is retailed in the streets at the price of one pice for approximately three gallons. It is therefore treated with great respect and rarely wasted.

There is no system of street drainage in the city. Storm water eventually finds its way into nullahs leading to a large tank, the Gindani tank, a short way from the city. Similarly storm water from the land around the city finds its way into a large stone lined tank, the Sursaga, near the Purana Kila. The absence of storm water drainage is at present a matter of minor importance in a city with such slight rainfall as Bikaner. Should, however, a piped water supply be laid on to the town, as has been suggested, the streets would be converted into quagmires, breeding mosquitoes and creating an insanitary nuisance.

No crops are irrigated in the vicinity of Bikaner, the natural rainfall only being relied upon.

The importance of the city depends on its position as capital of the State. There are no large industries, and owing to climatic conditions, there is little agriculture near by. The better class people are Government servants, lawyers, etc., or bankers and merchants, who leave Bikaner at an early age, spend the

better part of their working life in other parts of India, generally Bengal, and finally retire to Bikaner. There is thus a constant stream of travellers returned from highly malarious parts of India who must serve as a reservoir of infection.

Registration of vital statistics in the rural areas is unreliable. The registration of deaths within the municipal limits is believed to be almost complete, as all funeral processions are checked at the city gates. In the case of the population living within municipal limits, but outside the city walls it is thought that at least two-thirds of the deaths are registered. Thus 90 per cent of the total deaths within municipal limits are probably registered.

The climate shows extremes of temperature. Frost is often experienced in the winter, while the months of May, June and July are excessively hot. The average annual rainfall is 11 8 inches. Nine and a half inches of this falls in

TABLE I.

Normal mean monthly temperatures, humidity and rainfall for Bikaner city.

Month.	Temperature.		Humidity.	Rainfall (inches).
	Mean max. °F.	Mean min. °F.	Mean 8 A.M. (per cent).	
January ..	72·0	48·0	56	0·34
February ..	76·3	52·1	51	0·27
March	88·7	63·0	43	0·26
April	99·9	74·0	39	0·22
May	107·4	82·3	44	0·72
June	107·3	85·3	54	1·45
July	101·4	82·9	65	3·10
August	97·8	80·7	69	3·47
September ..	98·2	78·6	65	1·47
October ..	96·1	71·2	48	0·26
November ..	85·4	58·5	47	0·04
December ..	75·2	49·8	52	0·18

isolated storms, separated by several days or weeks of dry weather, between June and September. The mean monthly relative humidity remains low throughout the year, the highest records being seen between July and September. Table I shows the normal mean monthly temperature, humidity and

rainfall, derived from the Monthly Weather Reports, (1930) and Table II shows the monsoon rainfall by months, for the last ten years.

TABLE II.

Monsoon rainfall, Bikaner City, from 1921 to 1930.

Year.	Rainfall in inches.				Total.
	June.	July.	August.	September.	
1921 ..	0·49	9·58	4·67	1·89	16·63
1922 ..	0·21	4·74	0·39	3·07	8·41
1923 ..	1·47	4·24	3·28	0·21	9·20
1924 ..	0·48	1·06	2·41	3·54	7·49
1925 ..	3·71	2·32	0·00	0·45	6·48
1926 ..	0·00	4·85	4·29	1·17	10·31
1927 ..	0·70	3·99	2·19	0·37	7·25
1928 ..	0·32	3·16	6·35	1·71	11·54
1929 ..	0·04	7·20	0·79	0·34	8·37
1930 ..	0·58	3·27	1·43	0·00	5·28

The two climatic factors believed to control the transmission of malaria are the minimum temperature and the humidity. Of these two, the temperature is sufficiently high from April to October, but during the greater part of this time the humidity is in great defect. The observations of Richmond and Mendis (1930) show that the amount of malaria amongst British troops is closely correlated with the humidity, and marked transmission does not occur until the mean 8 A.M. humidity has reached 70 per cent. From the work of Bruce Mayne (1928) at least 80 per cent humidity would seem to be the optimum condition for the development of sporozoites. The normal mean monthly relative humidity in Bikaner never quite reaches 70 per cent, but remains at or above 65 per cent for three months, during which time temporary rises to 90 per cent or more may take place. It would thus seem that the climate of Bikaner is on the borderline of that at which the transmission of malaria is possible.

Bikaner City.

Anopheline mosquitoes.

Search in a series of houses in the city revealed the adult mosquitoes of the following species:—

A. stephensi 23 females, 2 males.
A. subpictus 4 females.

Of these two species, *A. stephensi* is a dangerous potential malaria carrier.

The potential breeding places within the city may be classified as follows:—

(1) Stone lined tanks. These are the collections of rain water, mentioned before, which have been improved by being deepened and stone lined. They vary in size from roughly 200 yards square, as in the case of the Sursaga, to some 20 yards square. In the majority of cases the walls are vertical, some 10 to 15 feet high, and steps are built in at each of the four sides. They are much used as bathing and washing places. In only a few cases were larvae (*A. stephensi* and *A. subpictus*) recovered from them. The impression gained was that no larvae could be found in tanks which were much used for bathing and washing, or from large tanks in which the wind produced a certain amount of wave action at the edges. Small tanks which were not much used, with walls sufficiently high to protect them from the wind, were on occasions found to contain larvae.

(2) Earthen tanks. These vary much in character, from definitely foul, sewage-laden collections such as the Gindani tank, to relatively clean collections used as bathing places. In no case were larvae recovered from really foul water. Clean and moderately clean tanks were found to contain larvae of *A. stephensi* and *A. subpictus* in sheltered, unused, corners.

(3) Collections of water at the bottom of bullock runs beside wells. These are extremely foul, and except in one case, when *A. subpictus* larvae were recovered, contained no larvae.

(4) Reservoirs beside wells. Water is temporarily stored in these after it has been drawn. They serve as excellent clean breeding places, and numerous *A. stephensi* larvae were recovered from all of those examined.

(5) Rain water cisterns, in which rain water is stored for washing and drinking purposes. Numerous *A. stephensi* larvae were to be found in these.

(6) Ornamental water. The Public Park, in which the Secretariat is situated, and which is beside the officers' colony, abounds in ornamental tanks. There are four large tanks beside the Secretariat and a number of fountains scattered throughout the Park. Twelve of these tanks and fountains were examined and larvae found in every one of them. They were mainly *A. stephensi,* with a few *A. subpictus.*

Amount of malaria present.

Spleen rates were taken in 14 schools within the city walls, in 3 schools within the municipal limits but outside the city walls, and in 6 schools in the adjoining township of Binesar and Gangesar. As education is compulsory within the municipal limits examination of school children gives a fair sample of the child population, and care was taken to examine schools in all parts of the town. The results of these examinations are set out in Table III.

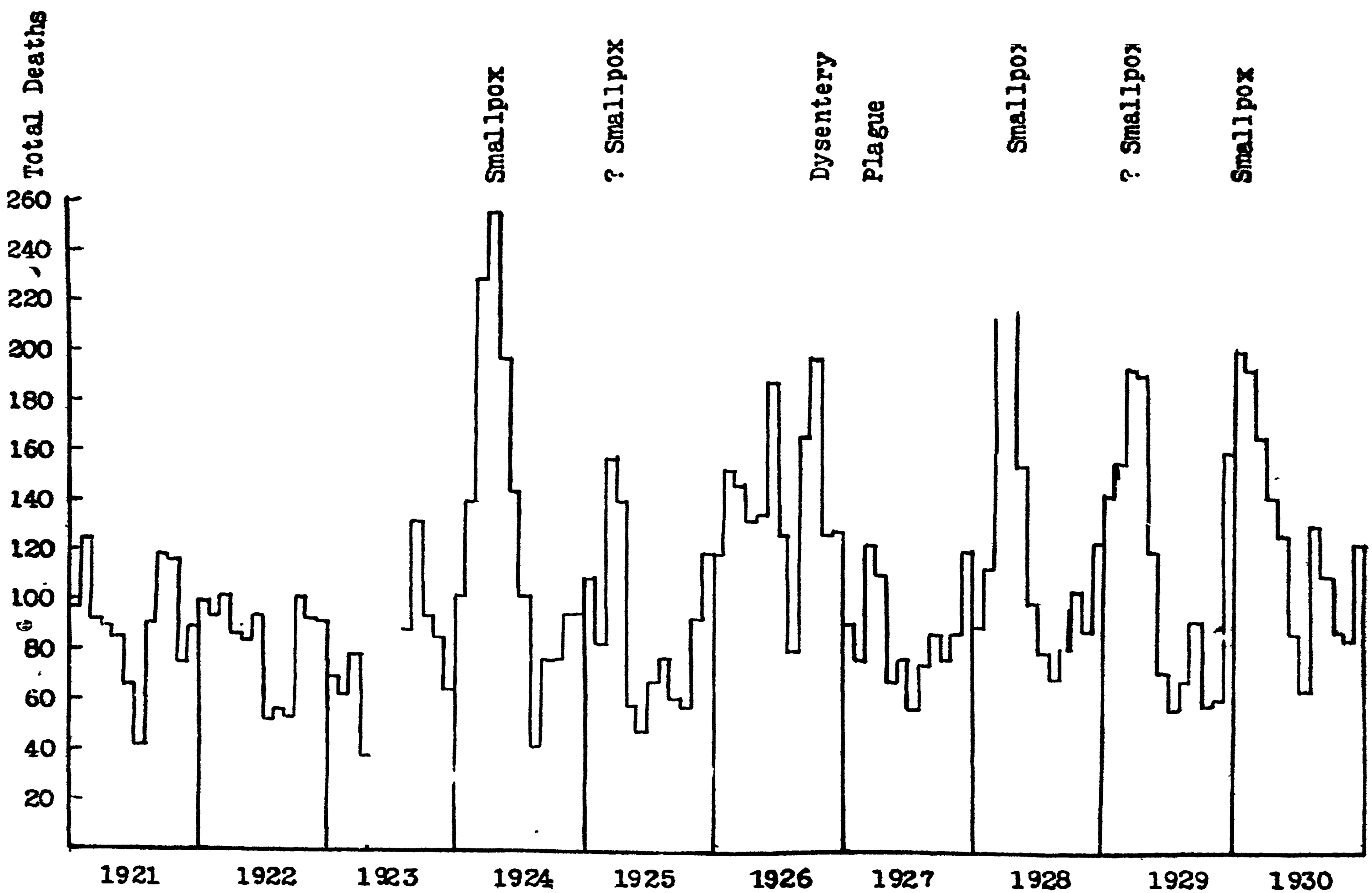
TABLE III.

Spleen rates in and around Bikaner City.

District.	Number examined.	Number positive.	Spleen rate. Per cent.
Within city walls ..	1,080	12	1·1
Outside city walls ..	146	1	0·7
Binesar and Gangesar ..	188	3	1·6
TOTAL	1,414	16	1·1

Of the sixteen children seen with enlarged spleens, two had recently returned from Bengal, and one from Jodhpur, while two others normally lived in villages some way away from Bikaner. The extremely low spleen rate of 1·1 per cent compares almost exactly with that of 1 07 per cent found by Ross, Christophers and Perry (1914) amongst children in the City of London. These observers, however, noted that all the enlarged spleens seen by them in London were 'just palpable,' none of them projecting below the costal margin. In the present series ten of the sixteen definitely projected below the costal margin. It would thus seem from the spleen rate that malaria cannot be considered to be present in a serious endemic form, but that occasional cases occur.

Examination of the mortality statistics of the city for the last ten years shows no evidence of any serious epidemic of malaria. The total number of deaths for each month is given in Table A in appendix, and is shown in graphic form in Graph I. The explanation of the epidemic rises is shown on the graph for those cases in which it can be traced. There seems to be no doubt that the epidemic rise in September and October 1926 was due to dysentery and not due to malaria. There was no excessive rainfall or other condition which might precipitate an epidemic of malaria at the time, and I am informed that the disease was definitely not amenable to quinine treatment. A slight rise in the number of deaths seems to occur normally in the autumn, but is so small as to make diagnosis of the cause difficult.



GRAPH I.—Total deaths, by months, in Bikaner City, 1921—1930.

The statistics of the Central Hospital for the last ten years (shown in Table B in appendix) show that an average of 12·8 per cent of the patients attending hospital are returned as malaria. The highest percentage was seen in 1930, with 16·6 per cent, and the lowest in 1925 with 8·8 per cent.

Conclusions and recommendations.

Anopheline breeding places, carrier species of anophelines, and gametocyte carriers, in the form of returned travellers, all occur in Bikaner City. The amount of malaria present is however extremely small. It is probable that owing to the extreme dryness the climate is unsuitable for the transmission of malaria, which might cease to be endemic in the absence of numbers of returned travellers from highly malarious places. A little transmission of malaria probably takes place every year in the vicinity of these infected persons, but it has never yet assumed an epidemic form amongst the general population.

Malaria is not, then, an annually recurring event to be feared. The possibility should, however, be borne in mind that in a year of exceptional rainfall transmission might take place on a large scale. This almost entirely non-immune population might then suffer from a serious epidemic, completely incapacitating the town and resulting in a large number of deaths.

Under these circumstances I am of the opinion that reliance should not be placed on anti-larval measures, except where grossly dangerous and easily treated breeding places exist. Thus the reservoirs beside the wells should be closed in with a concrete roof and the water drawn off by taps. The ornamental tanks in the Public Park should be treated, either by drying them, or treating them with kerosene oil twice a week from June to the end of September. Minor measures, attempting to control all the small breeding places in the city, would entail a large staff and heavy recurring expense. They would be opposed by the people, who would object to their valuable water being tampered with, and they would be unsuccessful. Several years of freedom from malaria would, in all probability, produce an unjustified feeling of confidence in the staff, who would only find the weaknesses in their organization on the outbreak of an epidemic. I therefore consider that the treatment of active cases of malaria should be relied on as more efficient and more economical than anti-larval measures.

In normal years quinine should be easily obtainable, free of charge, at all dispensaries, as is at present the case. Against the possible emergency of an epidemic a store of at least 500 lbs. of quinine should be maintained. This would be an annually recurring expense. The quinine should be purchased as soon as possible and kept in store, only being used when the Principal Medical Officer considers that the town is suffering from a serious epidemic of malaria. In this case the quinine would be freely distributed in the streets by dispensers, vaccinators, and other Government servants. The stock would have to be

made up to its standard size again immediately after the subsidence of the outbreak.

Such a store should be created immediately because the onset of epidemic malaria is extremely sudden. Few, if any, people realize that it is coming, and within a week or two of the first realization the town may be incapacitated. There is therefore no time to arrange for the purchase of quinine after the outbreak of the epidemic.

Lallgarh and Bijhey Bhawan.

These two palaces differ from one another in detail only, and they may therefore be dealt with together.

Anopheline mosquitoes.

Collection of adult mosquitoes in the servants' quarters, stables, and cattle sheds of Lallgarh revealed the following species:—

A. stephensi 7 females, 2 males.
A. subpictus 10 females, 1 male.
A. culicifacies 1 female.
A. fuliginosus 1 female.

Of these species, *A. stephensi* and *A. culicifacies* are dangerous malaria carriers.

Both of these palaces are surrounded by extensive gardens in which ornamental water is largely used. The potential breeding places may be classified as follows:—

(1) *Fountains.*—There are several of these in the gardens. They have two cast-iron bowls around the jet, the whole being surrounded by a marble well, from which excess water is allowed to run by an overflow pipe on to the grass. The well can be drained through a drain cock at one side. Water collections in these fountains remain in the cast iron bowls; in the surrounding well; in the sump into which the overflow water sometimes runs, and in irregularities in the bottom of the well after it has been drained. *A. stephensi* larvae, with a few *A. subpictus* larvae, were recovered from them.

(2) *Ornamental tanks.*—In the centre court of Lallgarh are four large tanks, fed by small fountains. A few *A. stephensi* larvae were found in these. In the main garden is a series of Moghul tanks. A serious fault in the construction of these is that the drain pipe is about one inch above the bottom level of the tank, thus preventing complete drainage. In some cases also the bottom of the tank slopes away from the drain cock. *A. stephensi* larvae were recovered from these tanks.

(3) *Goldfish ponds.*—Two large stone lined ponds containing goldfish were carefully searched. No larvae were found despite the fact that no

anti-larval measures were taken here. The goldfish are apparently efficiently larvivorous.

(4) *Water reservoirs.*—Drinking water is stored in an overhead tank, which was inaccessible at the time of my visit. Though roofed in this is not mosquito-proof. Water for the gardens is stored in concrete reservoirs, which were being cleaned and contained no larvae.

(5) *Water-butts.*—Water is stored in these for use on the smaller khuss khuss tatties. A single pupa of *A. stephensi* was recovered from one of them.

(6) *Waste water.*—Water from the garage, stables, cattle sheds, etc., runs in earthen drains on to the ground at the back. These had been oiled immediately before my visit and contained no larvae.

(7) *Miscellaneous*—water khundis, leaking hydrants, rain water pools, etc. No larvae were found in any of these at the time of my visit.

It should be noted that the fact that larvae were found in so many of the water collections at Lallgarh is not necessarily any reflection on the sanitary staff. The majority of the larvae seen were young, and those tanks in which they were found were due to be oiled on the following day.

The zenana garden of Lallgarh contains two long ornamental tanks, four small reservoirs, one large tank intended as a fish pond, and the usual leaking hydrants, etc. All of these had been oiled on the day before my visit and contained no larvae.

The garden of Bijhey Bhawan is very similar to that of Lallgarh on a slightly smaller scale. The tanks here had been treated with 'paristan' two days before my visit. Although signs of this could still be seen on the water surface, numerous half grown larvae were still present. The goldfish tanks are being newly stocked, and at present contain very few fish. In consequence a number of *A. stephensi* and *A. subpictus* larvae were found in them.

The zenana garden of Bijhey Bhawan has in it two long ornamental tanks. These were supposed to have been drained, but long pools, an inch or so deep, remained in the bottom. *A. stephensi* larvae were recovered from them.

Amount of malaria present.

The usual measures of malarial insalubrity, mortality figures and spleen rates amongst children, are not available for the palaces. The figures for the palace hospital, which are shown in Table C in appendix, show that an annual average of 2,782 cases of malaria are treated there. These figures include servants, labourers, builders, visitors' servants and people from outside the palace. They represent a very fluctuating population, and no attention can therefore be paid to their seasonal distribution.

Dr. Tipnis, the Palace Physician, has made a series of blood examinations on people attending his hospital, with the following results:—

Number examined	98
Negative	66
P. falciparum	8
P. vivax	42
P. malariae	1
P. vivax and *P. malariae*	1

Conclusions and recommendations.

The condition in the palaces is different from that in the city, where there is a minimal amount of transmission of malaria. Potential breeding places of dangerous carrier species of anophelines (*A. stephensi*) are very numerous. The liberal use of irrigation, ornamental water, khuss khuss tatties, etc., provides the humidity lacking in the city and in consequence transmission of malaria is probably of frequent occurrence here. In addition, the mosquito nuisance, apart from the malaria nuisance, has to be considered.

Reliance should be placed on the efficient prosecution of anti-larval measures throughout the year. The most effective treatment of ornamental tanks is to ensure that they are *thoroughly* dried once a week. During the winter they should remain dry for one day a week. During the summer the period of larval development is remarkably short; the tanks should then remain absolutely dry for two consecutive days. The interval of five days thus left between drainings should be too short for full larval development at any time of year.

All collections of water which cannot be absolutely dried once a week should be treated with oil, once a week in the winter, twice a week in the summer. Pure kerosene oil should be applied to ornamental tanks where crude oil might damage the stone work. Crude oil, or a mixture of crude oil and kerosene, may be used on other water collections.

Goldfish ponds, if well stocked, need little attention. They should be inspected at intervals to ensure that they do not contain larvae. In newly stocking a pond fish should first be allowed to multiply in small tanks, so that they are at all times sufficiently numerous to destroy the larvae in the pond in which they are living.

Overhead drinking water tanks should be securely closed by a steel roof, with a well-fitting manhole for inspection purposes. This will increase the intervals between cleaning, as well as preventing mosquito breeding. On account of their inaccessibility it is difficult to demonstrate anopheline larvae in them, but they form excellent breeding places for *A. stephensi.*

The principal requirement in dealing with mosquito breeding in the vicinity of the palace is efficient organization. The Medical Officer should have in his office a large-scale plan of the palace, the grounds, and all land within a half-mile radius. On this plan every water collection, or place where water might collect, should be marked and numbered. A plan of work should then be prepared providing for the inspection of every one of these places on a specified day of each week, and on two days during the months of June to September. It is the duty of the Sanitary Inspector to visit each of these places on the specified day and to certify that he has seen it properly treated, either perfectly dry, or thoroughly oiled. It is essential that treatment be carried out on the same day every week, otherwise at times intervals of more than seven days will be left between treatments.

A record book should be maintained in the hospital, showing the number of every breeding place, corresponding with that on the plan. Against each number the following particulars are entered weekly (1) date treated, (2) treatment (drying or oiling). The Medical Officer will then be able to keep a constant check on the work, and to make surprise inspections to ensure that it is being effectively performed.

GAJNER.

Gajner is a village of some 200 houses, or about 1,000 persons, 20 miles from Bikaner. Storm water from the surrounding country tends to run into a natural hollow near by which has been enlarged to form a lake, which is ornamental, and to which duck resort in the winter. Three small palaces, which are surrounded by extensive gardens, have been built beside the lake.

Anopheline mosquitoes.

Search in servants' quarters, and in stables, revealed the following species:—

A. subpictus 38 females, 1 male.
A. stephensi 2 females.
A. culicifacies 1 female.
A. pulcherrimus 1 female.

Of these species, *A. stephensi* and *A. culicifacies* are dangerous malaria carriers.

Potential breeding places are:—

(1) *The lake.*—This varies greatly in size with the season. At the time of my visit it was about half a mile long, whereas it is said to shrink to a hundred yards or so in length towards the end of the dry weather. That part of the edge opposite the palaces is stone-lined, deep water coming right up to the edge. Towards the eastern end, however, it is shallow, with a muddy bank, and the greater part of the bank is not stone-lined. Despite very careful

search no larvae were found at any part of the lake. It is said, however, that when the water level is slightly lower there is a series of shallow backwaters and pools, in which many larvae can be found, at the eastern end. This is the probable source of the numerous *A. subpictus* in the servants' quarters, the breeding places having been flooded out by a heavy rain storm, which raised the level of the water in the lake, a week before my visit. It is highly probable that dangerous species, *A. stephensi*, and possibly *A. culicifacies*, will breed in these as the water level subsides.

(2) *Ornamental water*—fountains, reservoirs, waste water, leaking hydrants, etc. These differ in no way from those in Lallgarh and do not require separate description. They had all been thoroughly oiled immediately before my visit, and no larvae were found in them. There is little doubt that if left untreated they would serve as breeding places for *A. stephensi*.

Amount of malaria present.

Seventy-two children in Gajner village were examined for enlargement of the spleen; 14 or 19 per cent, were positive. This indicates a considerable amount of malaria equal to that seen in the average Punjab village. Mortality figures are not available. The palaces have the reputation of being mosquito-ridden and highly malarious.

Conclusions and recommendations.

The vicinity of these gardens, with their lake, ornamental water, irrigation, and dense vegetation, to provide breeding grounds and to raise the humidity, are highly malarious. In addition to the malaria nuisance in summer there is said to be a severe mosquito nuisance in winter. This is probably due to culicine mosquitoes, breeding both in the lake and in the ornamental water. The two nuisances require different treatment.

In an attempt to deal with the malaria nuisance the gardens and all land within half a mile should be dealt with as described for Lallgarh. The lake should be watched for anopheline breeding, and when larvae are found they should be bred out and sent to Kasauli for identification. Immediately larvae are found, and without waiting for the identification, that part of the lake in which they are present should be treated with paris green diluted with slaked lime. The method of distribution of this, and other details, are fully described by Covell (1931). The expenditure involved in this would be a capital expenditure of roughly Rs. 125 on a Peerless Dust Gun, a screener and a mixer, with a weekly recurrent expense of not more than Rs. 2 in materials per acre of water treated. Thus some 1,500 yards of straight bank could be treated for this sum. The part-time labour of two coolies would also be required.

There need be no fear that the paris green or the slaked lime will be detrimental to any form of animal or vegetable life except the anopheline larvae.

Residents in the palace should always sleep under mosquito nets, and the rooms occupied in the evening should be efficiently mosquito-proofed.

Should it prove, as is almost certainly the case, that culicine mosquitoes breed in the lake during the cold weather, then the measures outlined above will not deal with the nuisance. Paris green will not kill culicine larvae. Oil or chemical larvicides cannot be applied to the lake as they would be detrimental to the duck. It is not certain, either, that training of the edges, preventing the formation of backwaters and pools, and thus allowing small fish to destroy the larvae, would be of much value, as the fish themselves would then be at the mercy of the duck. It would seem then that the only efficient method of dealing with this nuisance would be by mosquito-proofing of the palaces, and the present gauze doors cannot be considered as efficient mosquito-proofing. This would be an expensive procedure requiring the preparation of special plans and estimates. If the work is undertaken the plans should preferably be submitted to the Director, Malaria Survey of India, for his approval before being carried into execution.

The present system of issuing prophylactic quinine to the staff might be stopped, as it is the general experience in India that this is of little value as a preventive measure. Quinine should, of course, be freely available for those requiring it on account of sickness.

ACKNOWLEDGMENTS.

I have to acknowledge, with thanks, the assistance freely given by Dr. Bandowalla, the Principal Medical Officer, and other members of the Medical and Sanitary Staff, by the Education Department and particularly by Mr. Gokal Das Bias, a voluntary worker, without whose help it would have been impossible to examine so many of the school children.

SUMMARY.

A malaria survey of Bikaner City, Lallgarh and Bijhey Bhawan and Gajner palaces was made between July 19 and July 29, 1931.

The climate is extremely dry, the average monsoon rainfall is only 9·5 inches, and the relative humidity is rarely continuously high. Owing to the extreme dryness the climate is on the borderline of that at which the transmission of malaria is possible.

The following species of anopheline mosquitoes were encountered:—*A. stephensi*, *A. culicifacies*, *A. subpictus*, *A. fuliginosus* and *A. pulcherrimus*. *A. stephensi* is the principal malaria carrier.

The chief breeding places of *A. stephensi* are clean water reservoirs, tanks, and ornamental water.

The spleen rate in Bikaner City is extremely low, 1 1 per cent, and there is no evidence in the mortality statistics for the last ten years of any outbreak of malaria. It is considered that active anti-larval measures are not required in the city, and that reliance should be placed on treatment of active cases of malaria. A large reserve stock of quinine should be maintained for use in case of an outbreak of malaria in an exceptionally damp year.

An efficiently organized anti-larval campaign should suffice to keep down the malaria nuisance and the mosquito nuisance in Lallgarh and Bijhey Bhawan.

The spleen rate in Gajner is 19 per cent. This is due to its close proximity to large expanses of ornamental water, providing breeding places and raising the humidity. The smaller stretches of water should be treated with oil, while the lake should be treated with paris green during the malarious months of the year.

Efficient mosquito-proofing of the palaces is the only practical method of dealing with the winter mosquito nuisance at Gajner.

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APPENDIX.

Table A.

Total actual deaths, Bikaner City, **1921–1930.**

	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
January	97	99	69	101	108	118	90	89	161	198
February	124	93	62	139	82	151	76	112	174	191
March	92	101	78	228	156	145	122	214	191	164
April	89	86	38	254	139	131	115	218	189	140
May	85	84	..*	196	57	133	67	153	119	125
June	66	93	..*	143	47	186	76	98	71	86
July	41	52	..*	101	67	125	57	79	56	64
August	91	56	88	41	76	79	74	68	67	129
September	118	53	131	76	62	165	86	80	91	109
October	116	101	93	76	57	196	76	103	58	87
November	75	92	85	94	92	126	86	87	60	84
December	89	91	64	94	118	127	119	122	158	122
Total	1,083	1,001	..	1,543	1,061	1,682	1,044	1,423	1,395	1,499

* Figures for these months are not available.

Table B.

The number of outpatients and malaria cases attending the Central Hospital, Bikaner

Year.	Number of out-patients.	Number of cases of malaria
1921	21,511	2,657
1922	22,223	2,988
1923	24,237	3,130
1924	25,343	2,353
1925	28,273	2,489
1926	37,349	4,808
1927	29,416	3,312
1928	33,386	3,404
1929	35,776	3,472
1930	41,852	6,933

TABLE C.

The number of cases of malaria treated in the Lallgarh Palace Hospital, by months, 1925–1930.

	1925	1926	1927	1928	1929	1930
January	47	132	232	273	307	307
February	80	83	292	240	280	237
March	70	142	470	232	414	189
April	56	132	170	275	79	200
May	83	99	116	258	118	139
June	70	183	112	278	252	295
July	60	202	264	290	167	237
August	97	242	382	286	291	186
September	80	393	309	414	331	207
October	89	508	393	415	503	167
November	197	421	207	379	516	220
December	162	447	269	307	494	159
TOTAL	1,091	2,984	3,216	3,627	3,752	2,543

Records of the Malaria Survey of India, Vol. II, No. 4, December, 1931.

THE RELATION OF METEOROLOGICAL CONDITIONS TO MALARIA INCIDENCE AMONGST BRITISH TROOPS IN PESHAWAR.

BY

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[August 17, 1931.]

RICHMOND and Mendis (1930) in Part IV of 'A report on investigations carried out in Peshawar during the year 1927, in connection with malaria prevention among troops,' discussed the subject of the relation of meteorological conditions and malaria incidence, but it was not found possible to come to conclusions of any material value from the standpoint of anti-malarial measures in their military aspect.

Three years have elapsed since the carrying out of the original investigations, and it has been practicable to go more fully into this particular matter, and to take into consideration the meteorological statistics of the years 1928, 1929 and 1930, in addition to those of the preceding thirteen years (excluding 1919, in regard to which the requisite information is not available).

It is clearly of some considerable moment that we should, as early in the malaria season as possible, be able to forecast a bad year in regard to this disease, while the advantage which must accrue to a commander in the field, should it be possible to predict epidemic malaria among his troops in time to allow of the adoption of special and effective measures against such a catastrophe, is very manifest.

The taking of such special precautions, which will be referred to later, is always practicable with a definitely controlled population, such as a force on field service, and is feasible within limits in respect of a somewhat indefinitely controlled community, such as the civilian element of the average

cantonment, to which much of the malaria incidence among troops in peace time is presumably attributable.

It is essential for obvious reasons that if epidemic malaria is to be forecast, it should be done as early as possible in the season; and it would seem that, as far as Peshawar is concerned, and, presumably, the North West Frontier Province, forewarning of a bad malaria year should be given, if by any means possible, during the first two weeks of August, if the information is to be of material assistance to us.

As regards epidemiological factors to be taken into account in the prediction of malaria epidemics in the civil population, Gill (1927) gives us five:—

(1) The humidity factor, of which the July-August rainfall in the Punjab is the index.
(2) The spleen rate factor during the previous five years.
(3) The economic factor, of which the average price of food grains in the Punjab during the previous five years is the index.
(4) The 'epidemic potential' factor, of which the coefficient of variability of fevers during the month of October for the period 1868–1921 is the index
(5) The anopheline factor, as evidenced by the total prevalence of natural carriers during the months of July and August.

It is clear that in dealing with troops, and particularly British Troops as we are, certain of these factors do not require to be considered.

The spleen rate among them is negligible, presumably owing to the efficient quinine treatment they receive, while, similarly, it is not a factor of moment amongst Indian troops, where treatment is organised and under control. The economic factor does not affect us at all, as the troops are rationed equally well, practically speaking, in all years. Similarly the epidemic potential factor need not be taken into account.

Peshawar is outside the monsoon area, and there are enormous tracts of low-lying land with a very high level of subsoil water, and outcrops of it in innumerable places, outside the limits of our supervision; in addition, the cantonment and the land outside it are heavily irrigated, and it will be realized that, whether it rains or not, there are always plenty of breeding-places available for mosquitoes in the areas referred to at no very great distance from the cantonment boundary, which for various reasons cannot be controlled.

Also, irrespective of rainfall, the cantonment itself and adjacent land, for a distance of half a mile from the wire at many points, is kept under constant supervision, and mosquito breeding is effectively dealt with.

There does not appear to be, from year to year, any great variation in prevalence of the two chief malaria carriers, *A. stephensi* and *A. culicifacies*, and it is clear that, taking all the points mentioned into consideration, the

Anopheline factor in Peshawar may be discountenanced to a very material extent.

In comparison with the ordinary civil population one factor of importance as far as British troops are concerned alone remains, and that is humidity. The same applies to some extent in the case of Indian troops, but a large proportion of these proceed on leave to their homes during the hot weather, and consequently in their case, others of the factors named must come into play, as, at such times, they are living under the same conditions as the ordinary populace.

It is admitted that elements in the situation other than humidity must play a part in influencing the malaria incidence as regards British troops, among these presumably being:—

(*a*) The amount of fresh blood imported during the previous trooping season in the shape of recruits.
(*b*) Variations in the amount of malaria infection in units in previous years.
(*c*) Differences in the malaria prevention discipline of units.
(*d*) Variations in the extent to which men of different units go out of barracks at night.
(*e*) Variations in the amount of physical work performed.
(*f*) Differences in the amount of malaria infection in the native population.
(*g*) Variations as regards closeness of contact of barracks with local native habitations.

It will be realized that it is unlikely that in the case of years showing a moderately high or low malaria rate, we would be able to group them in order of severity of incidence by a study merely of one particular factor such as that referred to.

It is, however, contended that an analysis of the humidity statistics, together, possibly, with those in respect of rainfall and dry bulb temperature, might well enable us to forecast the bad and the good malaria seasons, and if this proved practicable, knowledge of some value would lie to our hands.

Having indulged in a preliminary survey of the points of importance in connection with the subject with which we are dealing, we will proceed to study the incidence of malaria among British Troops in Peshawar and the meteorological conditions obtaining during the years 1915 to 1930 inclusive, but excluding 1919, in regard to which we have no statistics available.

It will be agreed that as our admissions to hospital for malaria in Peshawar are confined practically speaking to a very definite period of the year, it is unlikely that a consideration of the average meteorological conditions during the whole year would be of much value, and, accordingly, we will examine first those existent in respect of what may be described as the 'danger period.'

The limits of this period were ascertained by scrutinizing the monthly malaria admission figures throughout eleven years, and ascertaining the dates between which most of the cases of malaria occurred. These dates were approximately August 15th to October 31st, and, allowing some 3 weeks for the development of the parasite in the mosquito and the incubation of the disease in man, we arrived at the period July 25th to October 10th as the danger period, as far as mosquito infection was concerned. The annual malaria incidence, together with the average humidity and total rainfall during the special period referred to, are given in Table I.

TABLE I.

Year.	Malaria incidence per 1,000.	Average relative humidity during danger period.	Total rainfall during the danger period.
		(Per cent)	(Inches)
1915 ..	332	64	0·8
1916 ..	585	78	11·7
1917 ..	469	76	8·5
1918 ..	264	64	1·6
1919 ..	Not available.		
1920 ..	193	64	0·4
1921 ..	514	69	1·9
1922 ..	369	72	6·0
1923 ..	479	73	6·7
1924 ..	398	71	3·7
1925 ..	386	70	6·0
1926 ..	496	75	5·6
1927 ..	490	73	2·0
1928 ..	188	70	0·4
1929 ..	574	66	6·3
1930 .	325	59	1·7

In Charts A and B at the end of this paper, the above figures are shown graphically, and a study of the two curves indicates in general a distinct relation between malaria incidence and both humidity and rainfall.

The rainfall curve appears to correspond more closely to that of malaria incidence, than does that of the humidity, but an examination of other charts

referred to later, and given at the end of this paper shows that a large proportion of the rainfall in the bad malaria years did not occur until the latter half of August, which would give us our rainfall statistics rather late in the year, though, it is admitted, not too late to be of some value.

Seeing that the heavy rainfall in the bad years occurred to such a large extent in the period July 9th to August 31st, I give, in Table II, figures indicating the years in order of severity of malaria incidence and the rainfall throughout this period, together with the order in which the years should have come had the malaria rate been dependent on the rainfall.

TABLE II.

	Years in order of incidence of malaria.	Malaria incidence per 1,000.	Rainfall July 9th to August 31st.	Order in which the years should have come if incidence were dependent on rainfall.
			(Inches)	
1	1916	585	10·8	2
2	1929	574	11·8	1
3	1921	514	2·4	9
4	1926	496	3·7	8
5	1927	490	1·0	10
6	1923	479	5·8	3
7	1917	469	4·9	5
8	1924	398	0·8	11
9	1925	386	4·2	6
10	1922	369	4·1	7
11	1915	332	0·3	15
12	1930	325	5·1	4
13	1918	264	0·7	12
14	1920	193	0·3	14
15	1928	188	0·4	13

A perusal of the figures given in this table afford, I think, sufficient evidence that the total rainfall during the period in question does not give us nearly as accurate a line on the malaria incidence as we would wish.

Referring to Table I again, it seems also that when a really bad malaria year like 1929 shows us during the danger period a comparatively low average humidity and medium rainfall, while 1928 with a moderately high humidity was a good malaria year; and when 1917 produces a high average humidity with the second largest rainfall of the fifteen years under review, and yet gives us a moderately high malaria incidence only; and when we consider the figures and charts in general, we are forced to the conclusion that the meteorological statistics during the danger period do not give an indication sufficient for our purpose of the amount of malaria each year, quite apart from the fact that the concluding date of the period is so advanced in the season as to be useless from the point of view of the early prediction of a high malaria incidence.

TABLE III.

	Number of ten-day periods showing average dry bulb temperature of				
Year.	Above 90°F.	86–90° F.	81–85° F.	76–80° F.	75° F. and below.
1915 ..	4	1	4	..	2
1916 ..	..	2	6	2	1
1917 ..	..	3	5	2	1
1918 ..	1	4	2	1	3
1920 ..	..	3	5	1	2
1921 ..	..	4	4	1	2
1922 ..	2	3	2	1	3
1923 ..	..	2	5	1	3
1924 ..	1	3	3	1	3
1925 ..	..	..	7	2	2
1926 ..	1	2	3	2	3
1927 ..	..	3	4	1	3
1928 ..	1	4	1	2	3
1929 ..	1	1	7	..	2
1930 ..	..	4	4	..	3
Average ..	0·7	2·5	4·0	1·0	2·4

Under these circumstances, and reviewing the information at our disposal, it was decided to approach the problem by another avenue and this consisted

in a study of the humidity, dry bulb temperature, and rainfall charts for each of the years under review, the humidity curve in each case being constructed on the average humidity for consecutive periods of 10 days from May 10th to October 17th.

The dry bulb curve was evolved in a similar manner, while the rainfall is shown in the actual amounts on the actual dates on which it occurred.

It should be noted in passing that the daily readings were taken throughout at 8-0 A.M.

These charts (Nos. 1–15) are reproduced at the conclusion of this paper, and appear to offer food for thought.

Taking into consideration in the first instance the dry bulb curves, an analysis of the readings is given in Table III.

A perusal of these figures enables us to subdivide the years with which we are dealing as follows:—

Hot.	Medium.	Cool.
1915	1916	1925
1918	1917	1929
1922	1920	..
1924	1921	..
1928	1923	..
..	1926	..
..	1930	..
..	1927	..

and if we refer once again to the years in order of malaria incidence in Table II, it does not seem apparent that the dry bulb temperature plays, *per se*, any very material part in influencing the incidence of malaria each year.

It is possible, however, that considered in conjunction with the humidity figures, it may be found to be a factor of greater importance than is indicated at the moment, and we will set aside any further study of the dry bulb temperature at present and turn to the humidity figures.

An analysis of the humidity curves for each of the years under review is given in Table IV.

Table IV.

Year.	Number of ten-day periods between July 19th and October 17th giving average humidity readings of						
	86–90 per cent.	81–85 per cent.	76–80 per cent.	71–75 per cent.	66–70 per cent.	61–65 per cent.	60 per cent and below.
1915 ..	..	..	1 (27. ix).	1	3	1	3
1916 ..	..	2 (8. viii, 18. viii).	4 (28. viii, 7. ix, 17. ix, 27. ix).	3	..	..	..
1917 ..	..	1 (27. ix).	6 (8. viii, 18. viii, 28. viii, 7. ix, 17. ix, 7. x).	1	1	..	..
1918 ..	..	..	1 (28. viii).	1	1	2	4
1920 ..	..	..	..	1	2	3	3
1921 ..	..	..	1 (8. viii).	2	4	2	..
1922 ..	..	..	1 (17. ix).	5	2	1	..
1923 ..	1 (28. viii).	..	1 (18. viii).	3	4	..	..
1924 ..	..	1 (7. ix)	1 (8. viii).	4	..	3	..
1925 ..	..	..	1 (29. vii).	3	3	2	..
1926 ..	..	4 (18. viii, 28. viii, 7. ix, 17. ix).	..	2	3	..	..
1927 ..	..	..	2 (18. viii, 28. viii).	2	5	..	..
1928 ..	..	..	2 (7. viii, 17. ix).	2	4	..	1
1929 ..	..	1 (8. viii).	2 (29. vii, 28. viii).	..	1	2	3
1930 ..	..	..	..	1	1	3	4
Average ..	0·07	0·06	1·5	2·0	2·3	1·2	1·2

From an examination of the annual malaria rates, it will be agreed that we are at liberty to classify the following years as good or bad as the case may be:—

Bad.	Good.
1916	1915
1929	1918
1921	1920
1926	1928
..	1930

If we study the statistics of humidity of these years in the analytical table just given we find that, with one exception (1921), the bad years show:—

(*a*) One or more readings of 81–85 per cent or 86–90 per cent in respect of the ten-day periods between July 19th and October 17th.

(*b*) The maximum average readings in respect of these ten-day periods are attained not later than that ending on August 28th in each year, nor earlier than the one ending on August 8th.

The good years mentioned:—

(*a*) Produce in no instance a reading of more than 80 per cent.

(*b*) Give no readings of 76 to 80 per cent prior to the ten-day period ending on August 28th each year, while only in the case of 1928 is more than one reading obtained within these limits, and then the second one occurred in respect of a ten-day period ending as late as September 17th.

It would appear from the foregoing that we have more or less definite grounds for stating that an excessive malaria incidence depends to a large extent on the occurrence of one or more ten-day periods with an average humidity of over 80 per cent, and with the maximum average readings for such periods falling between that commencing on July 29th and that ending on August 28th each year.

Conversely, a low malaria rate is dependent on the absence of any ten-day period producing an average humidity exceeding 80 per cent, and on those periods, in respect of which the average humidity is between 76 and 80 per cent, not occurring prior to the ten days ending on August 28th annually.

If we accept the above variations of the humidity factor as giving a reasonably clear line to the good and bad malaria years, it must be acknowledged at once that 1921 should not have given us the very heavy malaria admission rate which it actually did. The explanation is difficult to find at this length of time after the event. The year was a bad one not only for British troops, but for Indian as well, and a solution of the difficulty is not to be found in the rainfall, which was definitely small in amount. We can do no more than leave the matter at that, and realize that some other factor unknown must have played a heavier part than is normally the case. All sorts

of explanations could be offered, but they would, in the nature of things, be guess-work only.

1923 was high on the list as regards its malaria incidence, but according to our method of reckoning it might well have been a little higher still.

Turning our attention to the other end of the scale, we should have forecast 1922 as likely to be a good year, and lower on the incidence list than it actually was, and the same remark applies in regard to 1930. Both years were certainly low in the scale, and probably the explanation of their not being lower lies in the fact that the preceding year was bad in each case, with a consequent high relapse rate in the succeeding period of twelve months.

Also in 1930, on account of internal troubles and Afridi incursions, troops were very much more exposed than is normally the case.

Considering again the analysis given in Table IV, it is interesting to note that without exception all those years which give one or more ten-day periods with an average humidity of over 75 per cent in or before that ending on August 18th are in the top half of the list in order of malaria incidence and the remainder are in the lower half, and in this fact it would seem we have another rough guide to the annual malaria rate among British troops.

Earlier in this paper, reference was made to the dry bulb temperature, and it was thought possible that, considered in combination with the humidity statistics, it might be a more or less potent factor in the situation.

Apart, however, from the general impression gained from a study of Charts 1–15 that the worst malaria years show on the whole the greatest approximation, in the danger period, between the dry bulb and humidity curves, little of importance in regard to this particular element in the situation appears to emerge.

It is manifest that a study merely of humidity statistics on the lines given in the foregoing could not be expected, in view of other factors which must come into play annually, to enable us to place the different years exactly in order of malaria incidence; but it will, I think, be agreed that in the methods of forecasting by humidity suggested we have a means of predicting by August 28th each year at the latest, and frequently considerably earlier than that, the onset of a bad or good malaria season, as distinct from a medium one.

It is admitted that here and there we may find a year which we would not anticipate as likely to be a bad one producing a heavy malaria incidence, and vice versa, but on the whole, by adopting the methods outlined, it is considered that we should be in a position, to an extent sufficient in degree to be of very material value, to foresee a good, medium or bad malaria season early enough in August for our purpose.

Apart from those factors which may affect the malaria incidence, which have already been indicated elsewhere in this paper, others come to mind.

The treatment given to malaria patients probably varied considerably in the fifteen years with which we have been dealing, with consequent differences in degrees of efficacy as regards relapse prevention, while in some years presumably troops were more exposed to infection than in others, on account of disturbances of various kinds.

The mosquito-proofing of barracks, the increased 'cold storage' of troops during the malaria season, the use of prophylactic quinine, variations in the extent of anti-mosquito and anti-larval work, and other considerations must all also have played their part.

It is contended, nevertheless, that in non-monsoon areas to a large and, from the point of view of the moment, valuable extent, factors other than humidity, owing very possibly in some degree to a process of mutual cancellation out, will not change a predestined bad malaria season into a good one or the reverse.

We are not, however, on this account absolved from the responsibility of making, in the future, a deeper study of all the factors in the situation as they affect the malaria incidence among troops, with a view to arriving at the most accurate method we can of forecasting the malaria rate in any given year.

It seems likely that a high humidity enacts its rôle in producing a heavy malaria incidence at more than one stage in the life history of the parasite, and there is little doubt that in an excessively humid season, not only are conditions more favourable for the development of the parasite in the mosquito, and consequently, more of the insects become infected, but also very probably in such a season, gametocyte carriers amongst human beings are more numerous, and the gametocytes themselves are in larger numbers than normal in the blood stream of carriers; while possibly also the effect of a humid season on health in general causes more relapses than usual.

Under such circumstances, it is clear that, as regards very special measures to be taken in what is predicted as likely to be a bad malaria year, the increased prophylactic and curative use of quinine and plasmoquine is the first step indicated.

In the case of troops, this is easily catered for, as they are under very definite control, and apart from possibly increasing the daily dose of prophylactic quinine and making as effective use of plasmoquine as practicable in order to limit the number of gametocyte carriers and render gametocytes non-viable, special measures should be adopted to ensure adequate protection from mosquitoes of all patients discharged from hospital—especially those who have suffered from malignant tertian malaria—for a sufficient period to minimize to as great an extent as possible the risk of uninfected Anophelines becoming infected from them.

As regards the cantonment civil population, which is always the most fruitful source of infection of troops with malaria, in the face of a threatened bad season cantonment authorities should always be prepared to organize arrangements whereby quinine and possibly plasmoquine is made available free of cost at distribution centres throughout the area as a prophylactic measure, and under which special attention would be given to all malaria patients, and to their after-treatment.

It is not proposed to enlarge upon this matter, and it suffices to say that a little organization would effect all that was necessary, while the expense incurred would be largely offset by the saving of working days among the cantonment population, which would otherwise be lost.

It is believed also that measures of the nature outlined applied as a voluntary, as distinct from compulsory, scheme would have very beneficial results.

Although malaria is not normally included in the list of diseases regarded as infectious for the purposes of the Cantonments Act, 1924, yet under this act any disease may be placed on the list under the authority of the Local Government, when it is considered necessary; and, as we progress, no doubt such a course of action will become the accepted procedure in what threaten to be years productive of an epidemic incidence of malaria, together with the compulsory enforcement of special preventive measures.

As regards civilian populations adjacent to but outside cantonments, responsibility for any special precautions that are practicable lies with the civil health authorities, but will naturally not be as easy of achievement as in the case of a more or less controlled cantonment community.

In regard to the employment of prophylactic quinine among the troops, there would appear to be good grounds for considering that its employment or not should depend largely on the conditions and circumstances of the malaria season in regard to which a decision has to be come to as to whether to use the drug prophylactically or not, and that one condition of some importance in this respect is the outlook as to whether the season is likely to be a good or a bad one.

Apart from the measures outlined above, it should be possible under normal circumstances, when a bad malaria season threatens, to increase the period of 'cold storage' of the troops and their families, and with the aid of special funds which could presumably be kept in reserve for epidemic years to extend anti-mosquito work in barrack rooms and anti-larval measures outside, and in general to take special precautions to ensure strict obedience to all orders and regulations having malaria prevention as their object. In individual stations there must always be environmental factors in the situation which in ordinary years cannot receive attention for reasons of political expediency, too great interference with the recreation and comfort of the troops during the hot

weather, etc., but which might well be taken into consideration and dealt with in the occasional bad malaria season.

Finally it appears necessary to remark that though malaria among British troops only is dealt with in this paper, reference to the malaria incidence among the Indian troops shows 1929, 1921, 1926, 1930, 1923, and 1916 in that order at the top of the list and 1918, 1925, and 1928 at the bottom, the figures for 1915 and 1917 not being available; and it is interesting to note that here again 1921 was a very definite exception to our rule, while 1930 was much higher in the scale of incidence than it should have been. On the other hand, 1925 was nearer the foot of the list than might have been expected.

It will be agreed, however, that considering the additional factors in the case of Indian troops to be taken into account, the general relation of the incidence of malaria among them to the varying humidity statistics is clearer than one might have anticipated.

Conclusion.

(1) Humidity is the most important factor influencing the incidence of malaria amongst troops in the non-monsoon area of the North West Frontier Province, and the other factors combined, which must play their part, do not in the large majority of years exert a sufficient influence to detract materially from the value of the study of humidity as a guide to malaria incidence.

(2) It is during a very limited period of the year that the humidity factor is of importance.

(3) Bad malaria years are characterized by the occurrence of one or more ten-day periods with an average humidity of over 80 per cent, and with the maximum average readings for such periods falling between that commencing on July 29th and that ending on August 28th each year.

Good years are characterized by the absence of ten-day periods showing an average humidity of over 80 per cent, and by those periods in respect of which the average humidity is between 76 and 80 per cent not occurring prior to the ten days ending on August 28th annually.

(4) All those years with the higher incidences of malaria are characterized by one or more ten-day periods with average humidities of more than 75 per cent in or before that ending on August 18th; the remainder with the lower incidences are not so characterized.

(5) By the above means, we are in a reasonably satisfactory position as regards predicting bad years among troops in the non-monsoon area of the North West Frontier Province, and possibly work in other places might show much the same state of affairs in monsoon areas and in other parts of India.

(6) The dry bulb temperature does not on the whole exert any great influence on the incidence of malaria, possibly because, under the particular

conditions existent in the N. W. F. P. there is no very great variation in the different years, during the critical period.

In other parts of India, this factor is probably of greater account and would need more consideration.

(7) The method of predicting malaria incidence suggested is not absolutely accurate, and further study in future years of the factors involved is required, in order to evolve a still more efficacious means of forecasting if possible.

The author is indebted to Assistant Surgeon J. C. Mendis, I.M.D., in co-operation with whom the original investigations were carried out; also to Major W. E. Dimond, I.M.S., Assistant Director of Public Health, North West Frontier Province, and Captain W. R. Farrell, I.M.S., for help given in connection with statistics; to Jemadar Balwant Singh, I.M.D., for very valuable assistance and to Babu Lal Chand Khanna (I. C. C.) for typing this paper.

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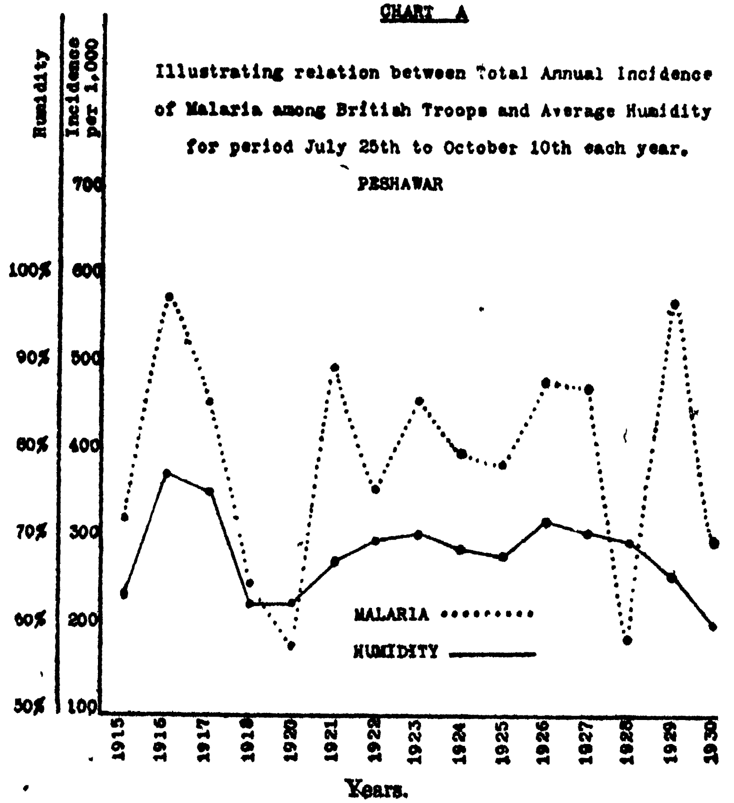
RICHMOND, A E., and MENDIS, J. C (1930). *Rec. Mal. Surv. Ind.*, **1**, 3, pp. 205–290.

CHART A



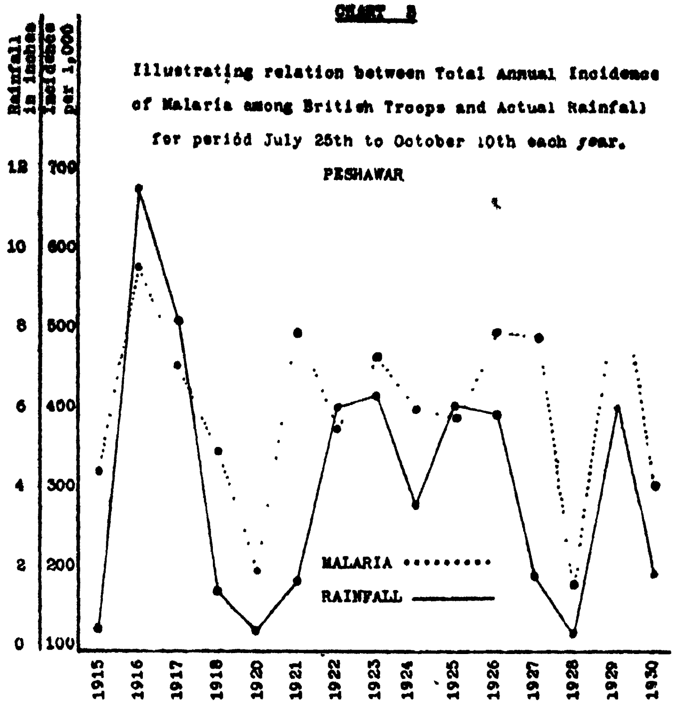
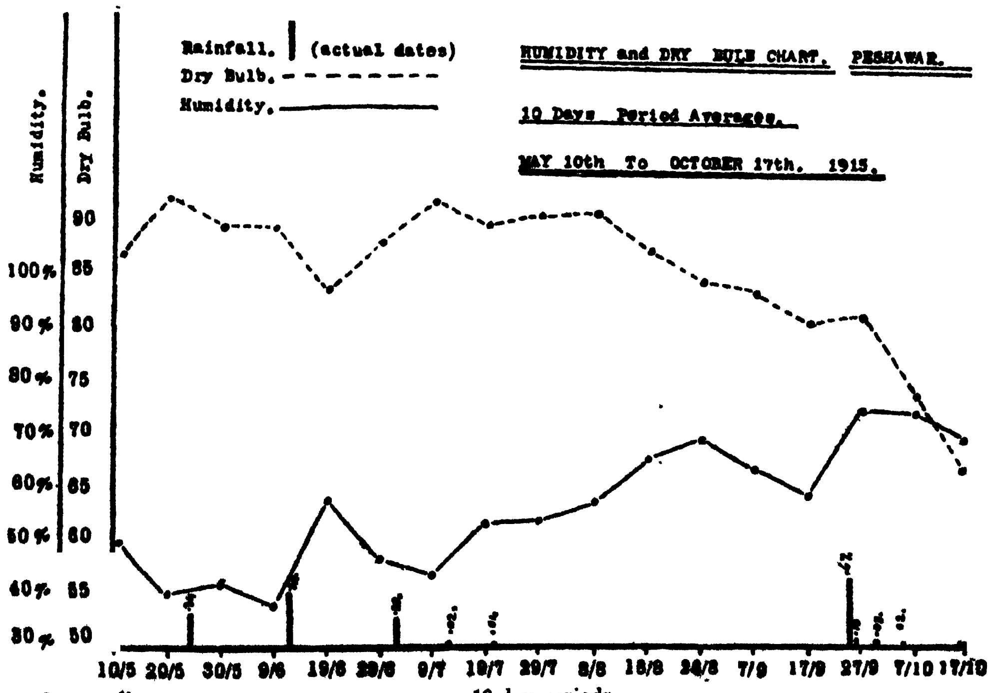


CHART 2
Rainfall in inches
Incidence per 1,000
Illustrating relation between Total Annual Incidence of Malaria among British Troops and Actual Rainfall for period July 25th to October 10th each year.
PESHAWAR
MALARIA
RAINFALL
1915
1916
1917
1918
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
Years.

CHART 1.


Rainfall. (actual dates)
Dry Bulb.
Humidity.
HUMIDITY and DRY BULB CHART. PESHAWAR.
10 Days Period Averages.
MAY 10th To OCTOBER 17th. 1915.
Humidity.
Dry Bulb.
10/5
20/5
30/5
9/6
19/6
29/6
9/7
19/7
29/7
8/8
18/8
28/8
7/9
17/9
27/9
7/10
17/10
10 days ending.
10-day periods.

MR

Chart 2.

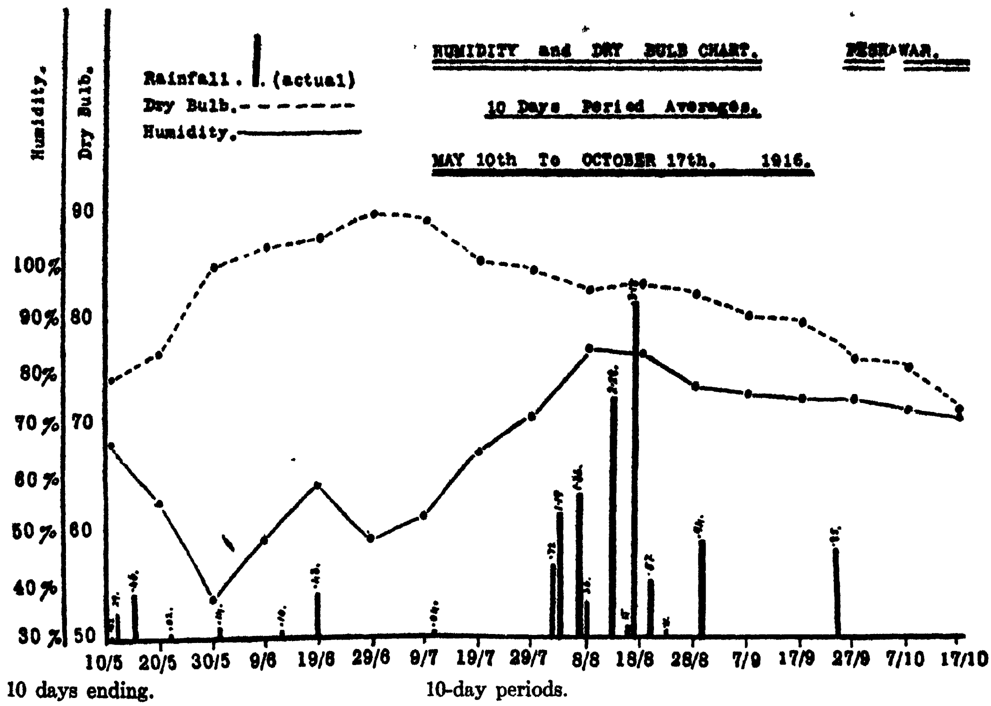


Chart 3.

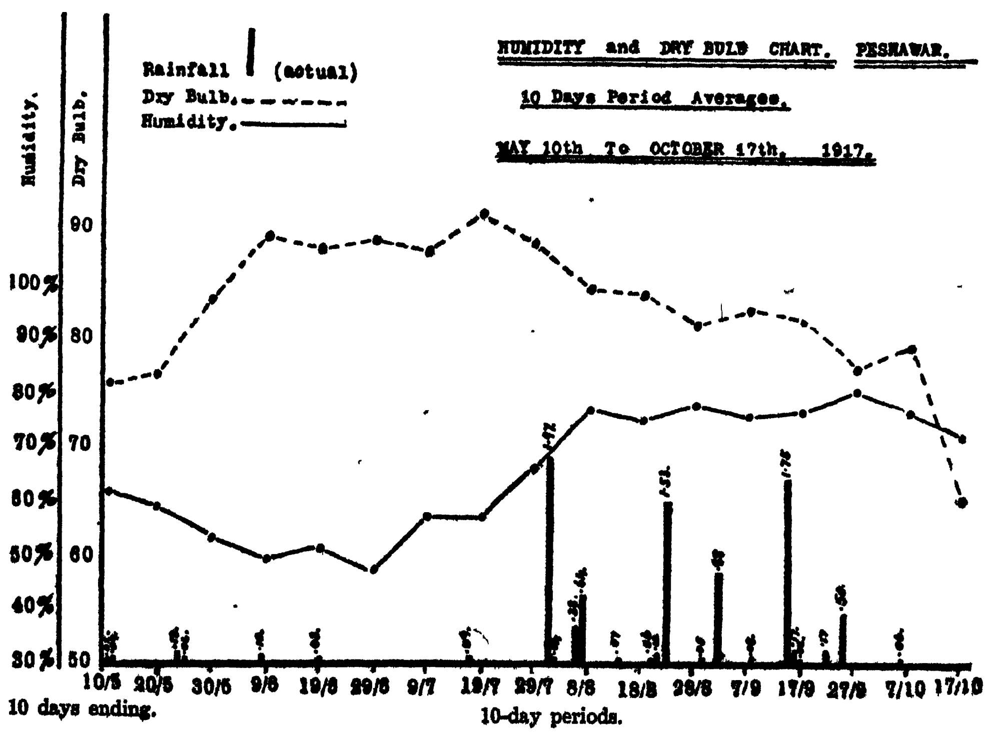


CHART 4.

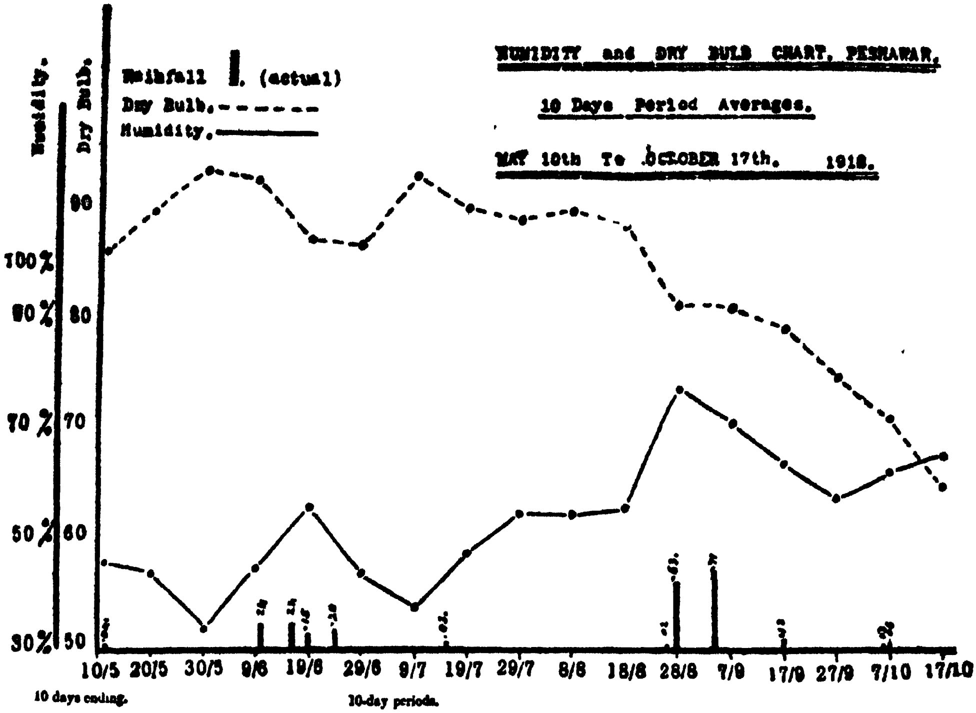


CHART 5.

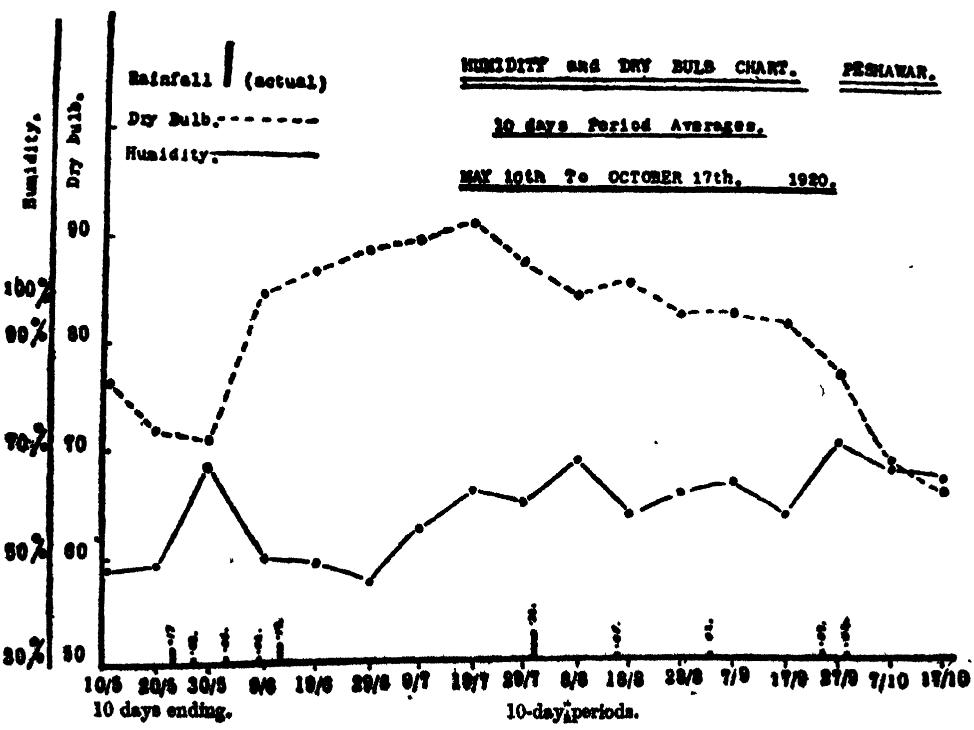


CHART 6.

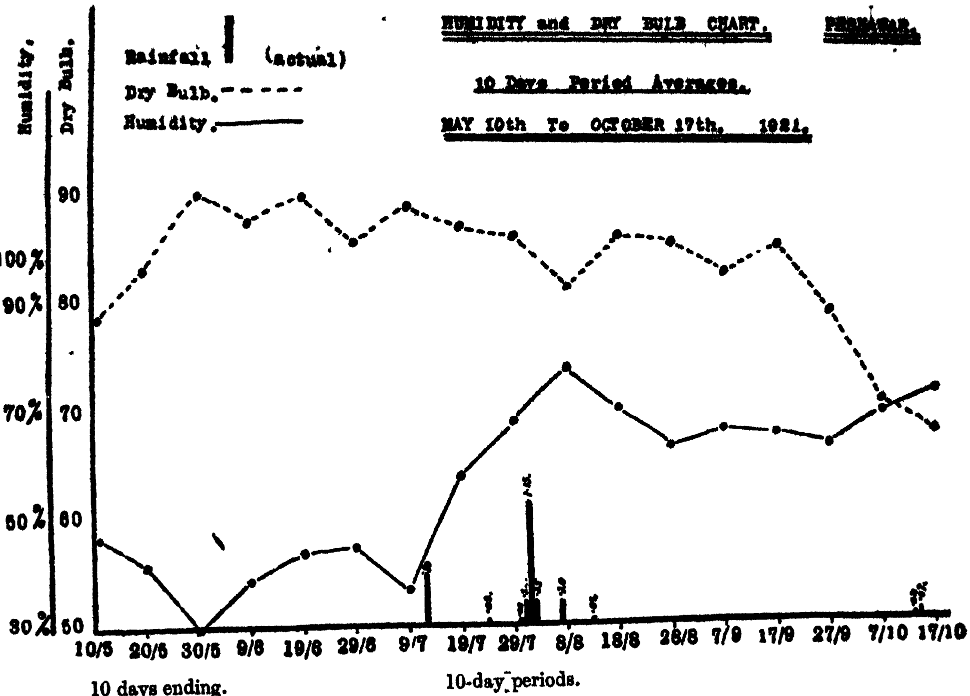


CHART 7.

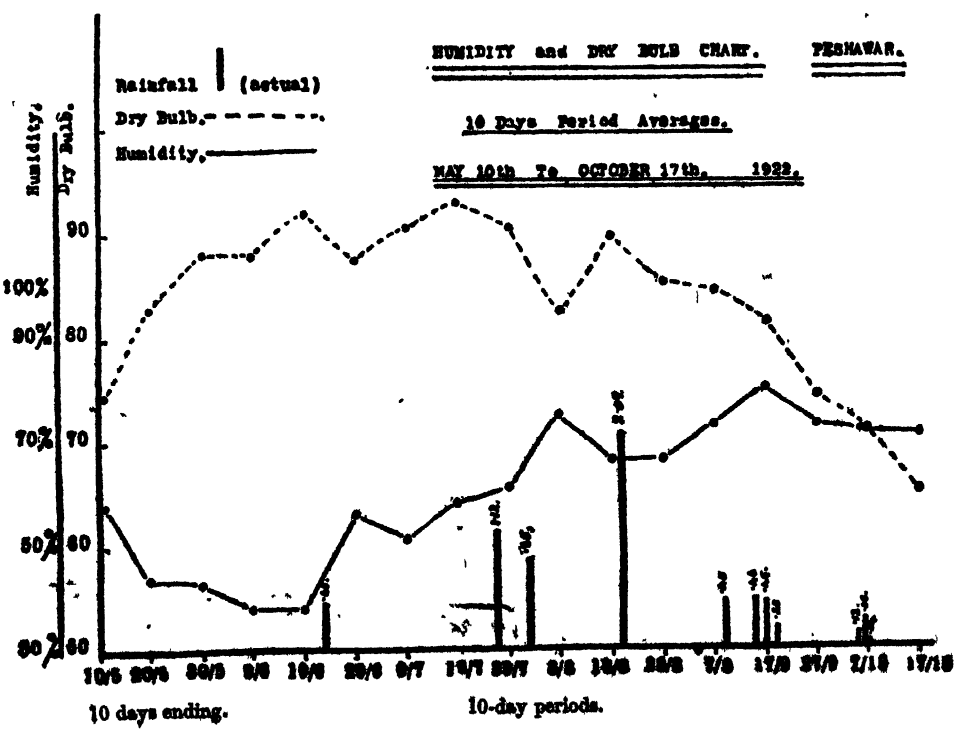


Chart 8.

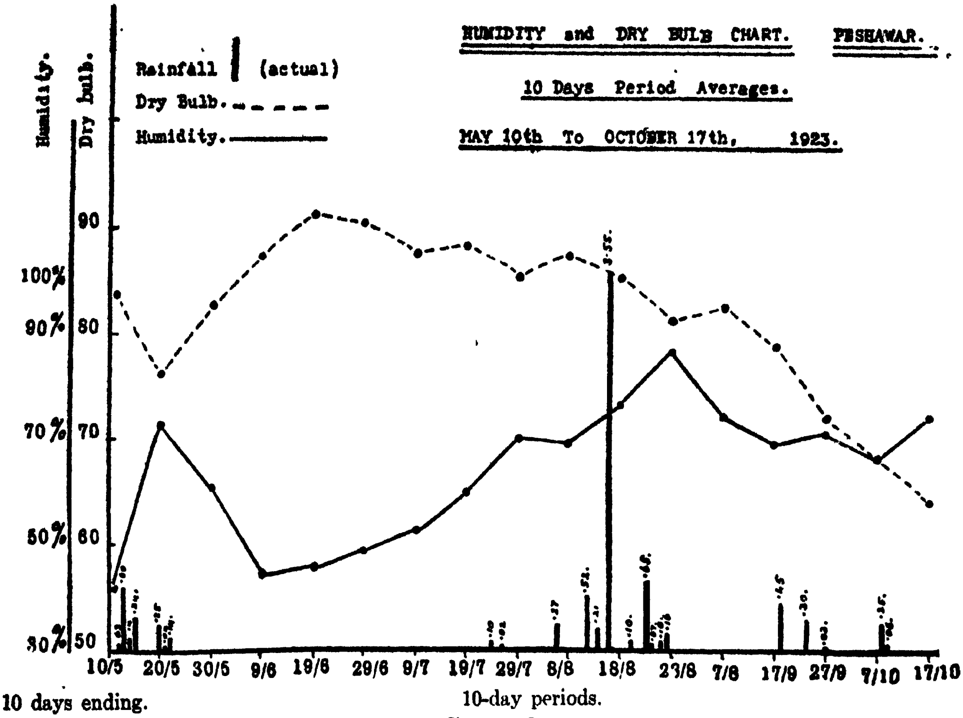


Chart 9.

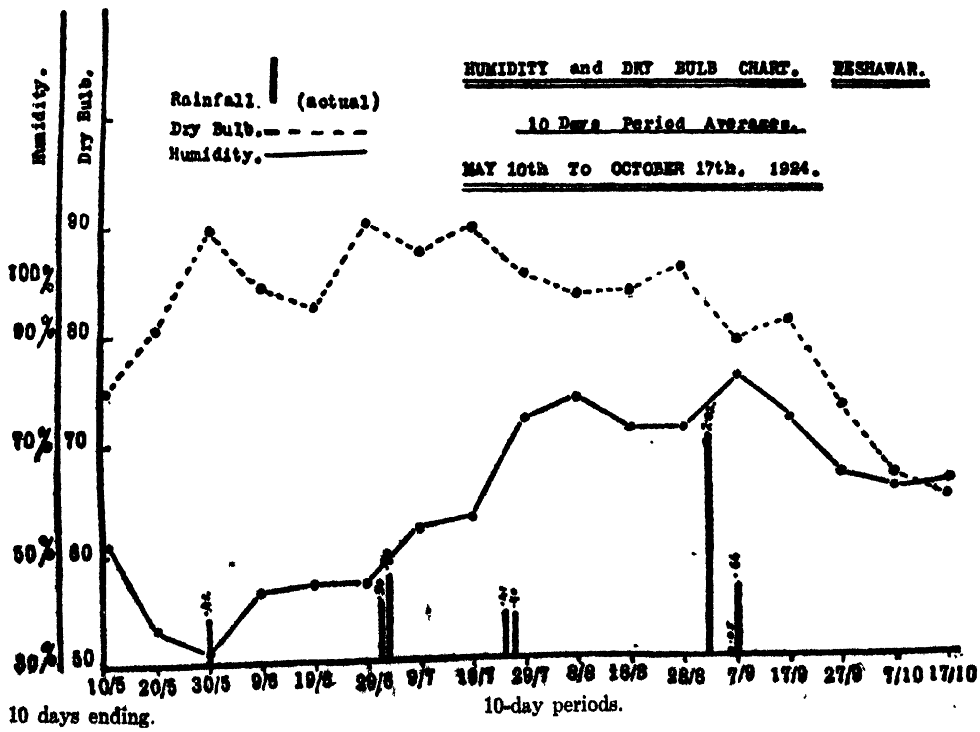
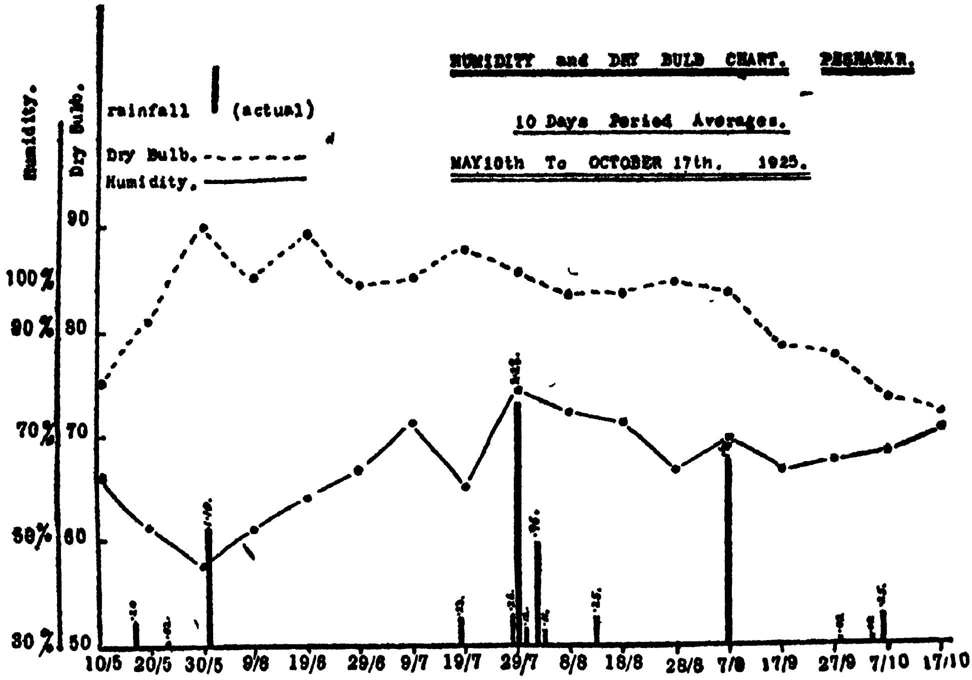
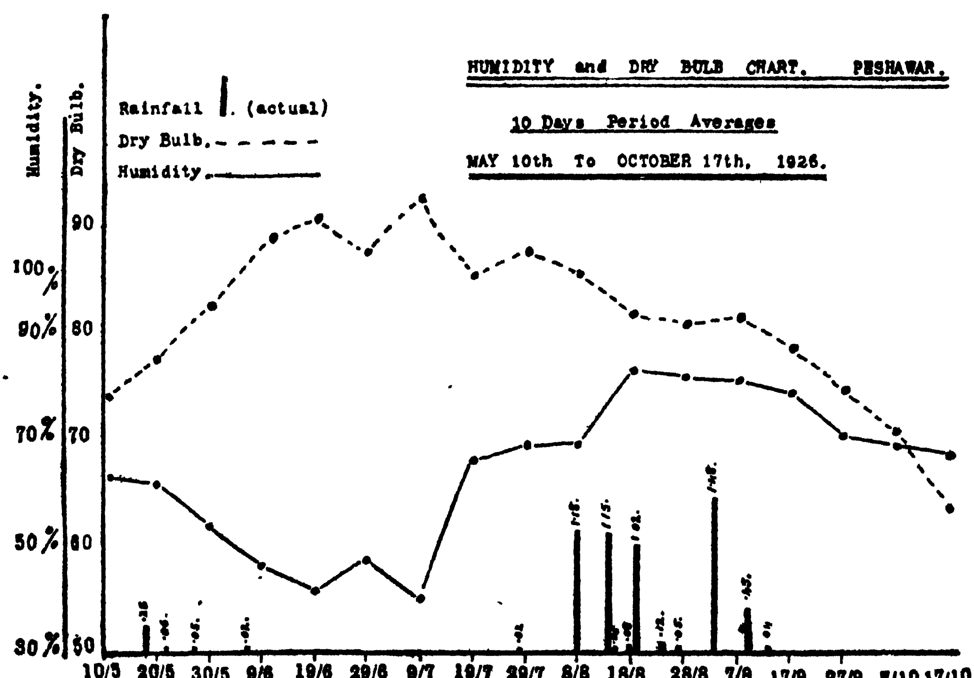


Chart 10.



10 days ending. 10-day periods.

Chart 11.



10 days ending. 10-day periods.

CHART 12.

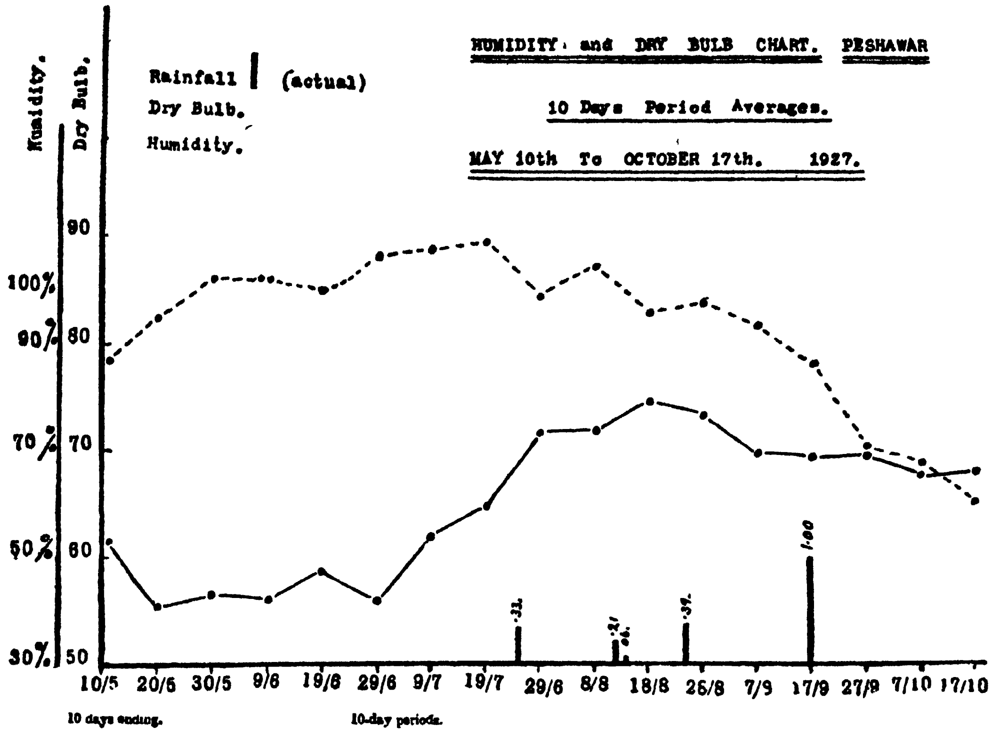


CHART 13.

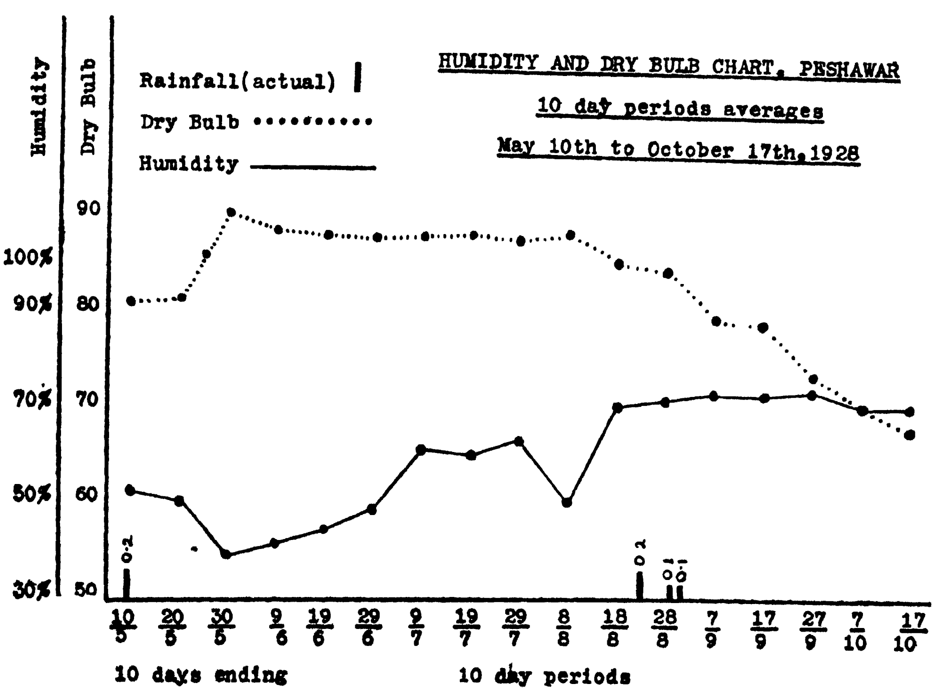


CHART 14.

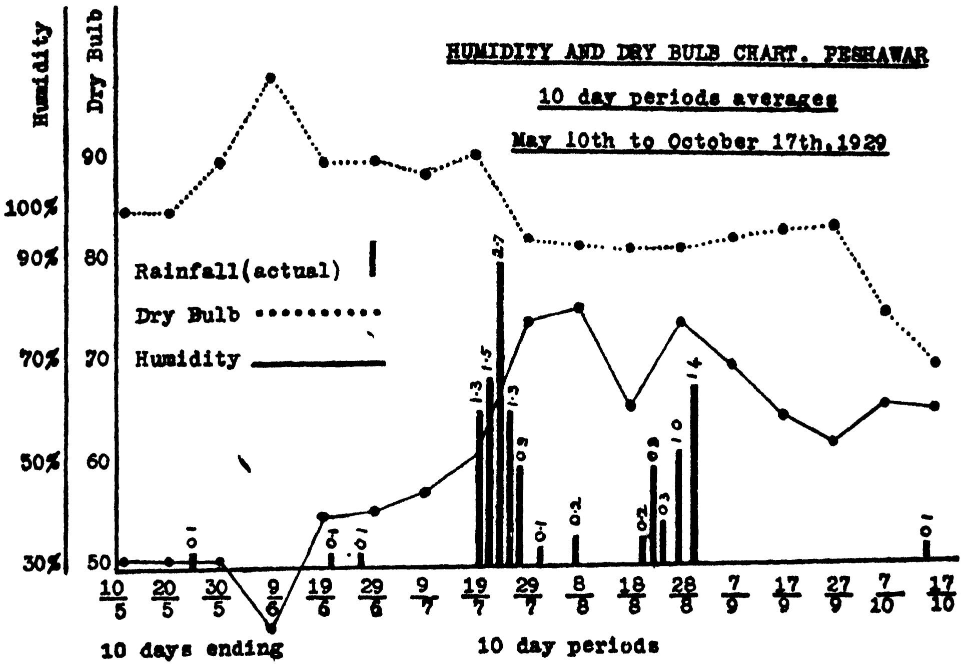
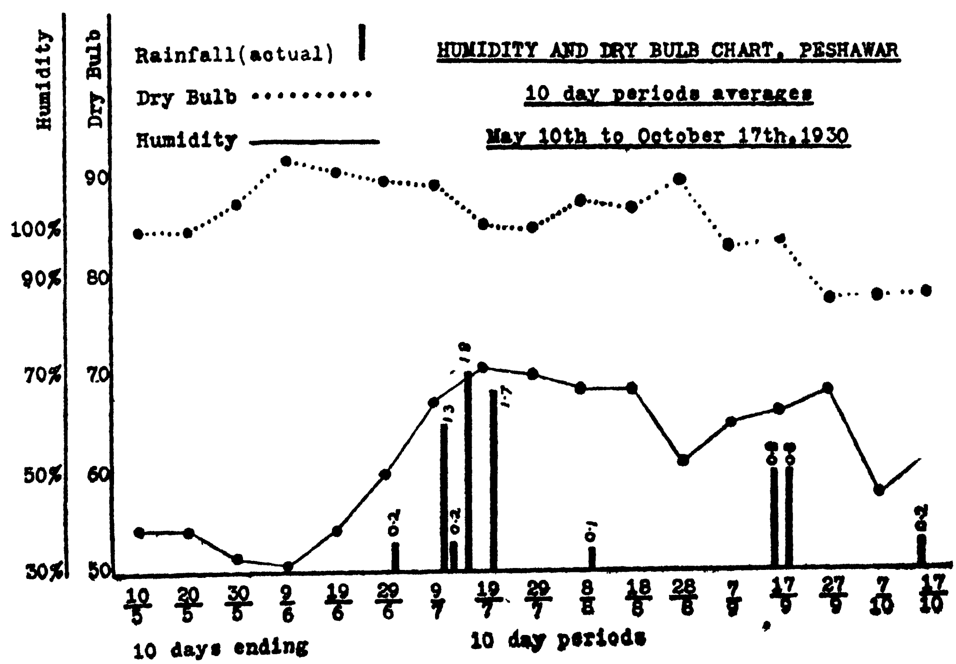


CHART 15.



Records of the Malaria Survey of India, Vol. II, No. 4, December, 1931.

OCCURRENCE OF *ANOPHELES GAMBIAE* (*COSTALIS*) IN ALDABRA ISLANDS (SEYCHELLES).

BY

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[July 6, 1931.]

THE Seychelles Islands consist of a group of 47 Islands and islets which lie in the Open Indian Ocean, to the north-east of Madagascar, between parallels 3° 42′ 20″ and 4° 66′ 30″ South Latitude and parallels 64° 12′ and 54° 46′ 20″ East Longitude, covering altogether a total land area of about 156 square miles.

Of this group, Mahé is the largest island, and being the most populous and also the seat of Government, it is the most important.

All these islands are mountainous and of granitic formation except Coétivy, Plate, Dennis and Bird Islands, which are flat coral islands on the edge of the Mahé bank.

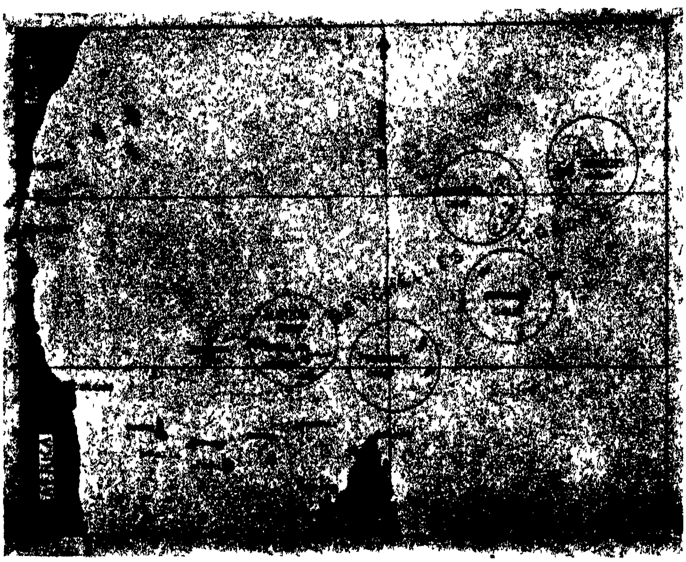
Under the dependency of the Seychelles there are other 45 flat coral islands and islets which form four more or less distinct groups on special banks, separated from the Seychelles group and from one another by ocean depths ranging from 1,000 to 3,000 fathoms, and situated south-west of Mahé at the following distances:—

Amirantes group	130 miles.
Alphonse group	250 miles.
Providence group	420 miles.
Aldabra group	630 miles.

These 92 islands together form the Seychelles Colony, with a population of about 27,000.

They were discovered by the Portuguese between 1502 and 1505 and remained unoccupied until 1753 when they were taken possession of by the French who colonized them from 1768 to 1810. In the latter year they were ceded to Britain and have since remained British possessions.

Throughout their history these islands have always had the deserved reputation of being extremely healthy and above all free from malaria and its transmitter, the Anopheles. Malaria has only been met with from time to time among individuals coming from India, Africa, Madagascar and Mauritius, where they contracted their infection.



On the 6th August, 1908, the late Dr. J. B. Addison (1908), Chief Government Medical Officer, Mahé, reported to the Governor of Seychelles, that the Manager of Aldabra Islands had arrived that day suffering from malaria, with parasites in his blood (there is no mention of the variety of plasmodium) and that according to the Manager there were several cases still in Aldabra.

Dr. M. S. Power (1908), Assistant Medical Officer, Mahé, left for Aldabra at the end of August 1908 to enquire into the matter. He was accompanied by Mr. J. C. F. Fryer, Shuttleworth Research Student of Caius College, Cambridge, who had come to Seychelles under the auspices of the Percy Sladen Trust, to explore Aldabra and certain neighbouring islands which had not been explored by Prof. J. Stanley Gardiner's Expedition in 1905, with a view to solving certain problems in connection with the existence in the past of a land connection between India and Africa and also the formation of the Coral

Islands of the Indian Ocean. They arrived at Aldabra on the 13th September, 1908.

Dr. Power's report (2. x. 1908 and reframed 27. iv. 1909) established the following facts (I give his own words):—

'1. Previous to April 1908 no case of malaria had been known to originate in any part of the Seychelles Colony (although many inhabitants had had attacks in Mauritius, Zanzibar, etc.).

2. An outbreak of malaria occurred 11 days after the arrival at Aldabra, during the last week of March, of S.S. *Longwood* which had on board some labourers from Nossi Mangû (Nossi Bé), suffering from malaria.

3. All the persons infected at Aldabra came from Mahé. Of 32 cases subjected to blood examination, the majority showed the plasmodium in their blood. (The variety of parasite is not mentioned, but in his report Dr. Power, evidently speaking clinically, stated that there was no doubt as to the fever being malaria of a mild character and mainly "benign tertian" in type with a few isolated instances of "quotidian.")

4. From April until September 1908 the cases gradually increased in number, 91 cases occurring during July and August; then a progressive diminution in severity was noticed, the earlier cases being the more severe.

5. After the removal to Mahé of the worst cases and treatment of the others with quinine, the outbreak ceased suddenly and no fresh cases occurred.

6. The outbreak was confined to the settlement on Picard Island.

7. The existence of the Anopheles has been denied by many investigators.

8. All water tanks and pools on Picard Island were searched for Anopheles by Mr. Fryer and myself but the search was fruitless, the only larvae found being those of "culex" and "stegomyia."

9. Further exhaustive searches were made by Mr. Fryer (1910) from October to January with completely negative results.'

At this point, it will be interesting to quote from a paper by Mr. J. C. F. Fryer (1910):

'In March 1908, there arrived a ship carrying Malagasy labourers from Nossi Bé, Madagascar, a locality noted for malaria. In about three weeks many of the negroes began to suffer from attacks which corresponded exactly with tertian ague. During May, June and July, the number of cases rapidly increased and several were sent to Mahé, where Dr. Addison confirmed the character of the disease by the examination of blood films. Dr. Power also considered the disease malaria, and indeed, from the blood films, the periodicity of the attacks, and the yielding of the disease to quinine, I feel no doubt that the diagnosis is correct. During August 1908 the number of fresh cases began to diminish and the last fresh case occurred at the end of September, while at the end of January 1909 the atoll was free from the disease. On my arrival

I searched with the greatest care for Anopheles either in the larval or imago stages and I feel confident it does not exist in Aldabra.

The explanation of the epidemic, I would suggest, is that though it is proved that Stegomyia is not a host for the malaria parasite, yet that it can convey it passively—that is to say, if a Stegomyia bites a patient suffering from an attack and then bites an unaffected person, it is possible for the latter to contract the disease, for in the act of sucking, a little blood (containing sporulating malarial plasmodia) of the infected person, will be injected into the unaffected. This explanation also accounts for the decline and extinction of the disease, for in the absence of Anopheles no sexual processes are possible and the stock of the protozoan will become senescent and die.'

The following remarks were passed by the President of the Royal Geographical Society after Mr. Fryer had read his paper: 'Mr. Fryer's observations on mosquitoes are exceedingly important, because, if he has indicated a true conclusion, the mosquitoes, which we originally thought harmless, can carry disease from one person to another, and new views must be adopted of the precautions to be taken with regard to Malaria in hot climates.'

In his last memo to the Governor (12. 3. 09), Dr. J. B. Addison (1908) put forward as his chief objection to Mr. Fryer's theory, that if it were possible for the ordinary mosquito to carry the infection, why had such never happened in Seychelles where the ordinary mosquito existed and where it was by no means rare for people to come with their blood full of malaria parasites.

Fortunately Mr. Fryer's theory can be safely dismissed as untenable. Either the fever was not malaria or Anopheles did exist. After the epidemic of 1908, however, malaria was never heard of again in Aldabra until 1930.

Between the 17th July and 27th September, 1930, I was consulted by seven individuals coming at different dates from the island of Assumption (30 miles from Aldabra) and suffering from typical clinical acute malaria. Of these a woman aged 38 and a boy aged 6 had enlarged spleens. No parasites were demonstrated but the fever yielded at once to quinine in the classical manner. At least four of the patients had never resided elsewhere than in Mahé and Assumption, including the boy of six with splenomegaly. The manager further informed me that he had never seen so many mosquitoes in Assumption as in 1930 and between June and October his hospital was always more or less full with cases of severe fever while there were also mild cases in the lines. None had any cough, a symptom which characterized fever cases of the previous years. (This of course would not necessarily exclude malaria, especially of the subtertian type which can be most protean in its clinical manifestations.)

Between the 29th October and the 12th November, 1930, I was further consulted by six individuals recently arrived from Aldabra and suffering from acute malaria. Of these a boy aged six had a markedly enlarged spleen with secondary anæmia, four cases showed gametocytes of *Plasmodium falciparum*

(crescents) in their peripheral blood, none had resided elsewhere than in Mahé and Aldabra, and one of them, a young sailor from Mahé, had slept only one night at Aldabra. The latter and the boy of six with splenomegaly were among those who showed crescents in their blood.

Having secured these positive and indubitable data, I reported the matter on the 18th November, 1930, to the Governor of Seychelles, pointing out my findings which conclusively proved the existence of Anopheles in Aldabra and probably Assumption islands, and urging the necessity of taking immediate steps to have a survey made of these islands to determine the variety of Anopheles present, the best way of dealing with it there and to take measures of prophylaxis against their introduction into Mahé and the other islands of the colony.

The majority of the population of this colony are poor; local industries are barely sufficient to keep them in average comfort; individuals suffering from malaria are constantly coming in from Africa and India, and invasion of these islands by the Anopheles would be the biggest calamity that could possibly assail the colony.

Aldabra and Assumption are served from Mahé mainly by schooners which are anything but rapid and whose water arrangements are primitive, ideal factors for the conveyance of mosquitoes and their larvae.

While my report was being considered by Government I entrusted to an employee going back to Aldabra, the task of collecting adult mosquitoes and larvae for me. A first batch of adults and larvae sent by him contained no Anopheles but a second batch of larvae contained some which proved to be those of *Anopheles gambiae* (*costalis*). Adults were, however, not available.

The Government by this time had decided to send Dr. A. K. Matthew, M.B., Madras, Assistant Medical Officer, Praslin, to visit Assumption and Aldabra and report upon the matter. In his official report dated 23rd February, 1931, Dr. Matthew (1931) stated that he had found no Anopheles in Assumption but had found one variety at Aldabra, breeding profusely in the neighbourhood of the settlement on Picard Island, and had succeeded in demonstrating asexual rings of *Plasmodium falciparum* in the peripheral blood of each of several cases suffering from fever during his visit. Before leaving the island he oiled 966 pools of water, in 281 of which he had found Anopheline larvae.

The report contained no mention of the variety of Anopheles. Interviewed personally Dr. Matthew was unable to say which variety he had found, and being unable to obtain specimens from him, I decided at once to send Mr. Armand Morel du Boil, my dispenser and laboratory assistant, to Aldabra. He left at the end of March with a complete outfit for the collection of larvae and adults, bred from larvae for purposes of classification, and free-living adults for purposes of sectioning, in the hope of demonstrating natural infection (dissection not being possible under the circumstances).

The weather being somewhat dubious, and the captain of the schooner fearing a cyclone, remained at Aldabra only one night and part of the next day. In spite of this short time and of the fact that Dr. Matthew had oiled 966 actual and potential breeding pools, Mr. Morel acquitted his task successfully and with credit. He collected during the night, in the manager's bungalow, 15 adult females which he preserved in Bles fluid. Next morning he examined the pools that had been oiled by Dr. Matthew. Half of them were dry but out of the others still containing water, none contained a single larva. After careful search for fresh breeding places he found several pools containing larvae which he collected. Having noted carefully the nature of the ground over a wide area and taken photographs of breeding places, he returned to the schooner with his collection. Under sail, he proceeded to breed out adults from the larvae, in muslin cages specially made for the purpose. He arrived after an absence of five weeks, with larvae and free-living adults preserved in Bles fluid, numbered pinned adult males and females complete with the corresponding larval and nymphal skins, and also specimens of water from the breeding pools for determination of the hydrogen-ion concentration.

The water after twenty days in clean bottles gave a pH of 7·5, a degree of alkalinity which one would expect from the action of rainwater on the coral rock.

All the specimens of his collection whether larvae or adults and about fifty adults in a dried condition collected during the previous few days by the manager of Aldabra and handed to Mr. Morel, proved to be of one and the same variety—*Anopheles gambiae (costalis)*.

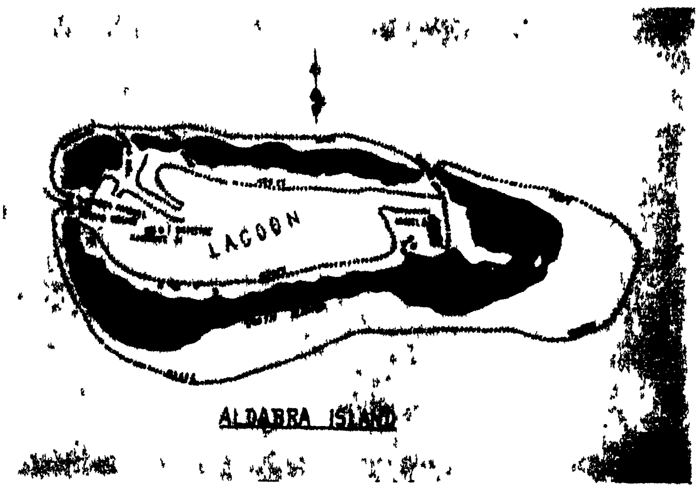
Breeding places at Aldabra.

Aldabra, in form, is an atoll with a long axis of about 24 miles running approximately east and west and a short axis of from 5 to 10 miles. The land rim measures some 60 miles in circumference and averages a mile in width, though at its widest it is nearly 5 miles from lagoon to sea. It is divided by narrow passes into four main islands which are called respectively Picard, lying to the north-west, Polymnie and Malabar, to the North and Main or South Island completing the circumference from the north-east to west.

The lagoon shore of the land rim is overgrown with dense mangrove swamps which at their greatest width measure about a mile. The lagoon itself is 15 miles long and averages 4 miles in width and has an area of 50 square miles.

According to Fryer (1910) and other observers before him, the atoll is a coral reef which has been elevated in relation to the surface of the sea. The greater part of the land consists of coral rocks still in their position of growth, part of which has been metamorphosed, phosphatized and turned into various sandstones. In several localities it has been found that the sandstones contain iron

and alumina which according to Dupont* are derived from pumicestones, originating from volcanoes in the neighbourhood, which were carried ashore and thrown far inland by spring tides. This rocky surface is seldom covered with soil, while under the influence of rainwater denudation it has been so eroded as to form a miniature forest of points, pinnacles and sharp edges, known locally as 'champignions' which are very formidable to men with bare feet and indeed difficult to negotiate even by men properly shod Scattered all over in this hardened conglomerate foundation are natural depressions or pits of irregular sizes which during the rainy season become filled with rainwater forming pools of depths varying from an inch or two to two or more feet. This type of surface is constantly associated with *Phemphis* jungle, which is



largely composed of *Phemphis acidula* (locally known as Bois d'Amande) amongst which are scattered trees and shrubs of other species, the next commonest being *Euphorbia Abbotti* (locally known as Tanghin). Herbaceous plants on the other hand are very scarce.

The *Phemphis* plant varies from 10 to 15 feet in height and consists of a short thick trunk from which a number of tall thin branches arise. With its narrow pinnate leaves of a bluish green colour, a single plant is not unlike a willow, but in the jungle the trees grow so close together that the whole is rather reminiscent of a continuous well-grown whitehorn hedge.

Such is the ground on Picard Island where the main settlement of the group is situated, and where *Anopheles gambiae* (*costalis*) has been breeding so profusely. These thin-leaved trees while affording a certain amount of

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* Private communication from Mr. P R Dupont, Director of Agriculture, Seychelles.

protection allow at the same time the rays of sunlight to reach the pools, a condition of affairs which suits this Anopheles admirably.

The photographs in Plate I show typical breeding pools on Picard Island.

Failure to find Anopheles at Assumption Island.

Assumption is situated about 30 miles south-east of Aldabra and is geologically similar to Aldabra, although not itself an atoll.

Both Dr. Matthew and Mr. Morel were unable to find Anopheles there, but they each spent a very short time (5 and 2 days respectively) on the island, at a time when most of the pits were dry (February and April). As nothing can explain the malarial infection of the individuals from Assumption except the presence of the vector, the absence of water, combined with a not sufficiently prolonged search, would suggest that the mosquitoes after being active from June to October during the rainy months must have been undergoing a period of aestivation and hence the failure to find either adults or larvae.

At Aldabra on the other hand there had been a good deal of rain, the pools were full of water and reproduction was at its height.

A survey of Assumption at the proper season is therefore indicated.

How long has the Anopheles existed at Aldabra?

Although this is a problem of chiefly academical interest, it would nevertheless be of some importance to solve it, but the question is a difficult one to answer at this stage, especially as several contradictory facts are involved.

1. Epidemic of benign (?) tertian malaria (May to September, 1908) (Addison and Power).

2. The non-existence of Anopheles in that year (Fryer).

3. Complete disappearance of malaria from the island from 1908 to 1930. (This assumed fact is possibly open to question.)

4. Epidemic of subtertian malaria (October to January, 1930) followed by discovery of *Anopheles gambiae (costalis)*, a renowned Ethiopian transmitter of malaria, breeding in profusion at least on the western island of the atoll (Picard). (Epidemic at Assumption June to October.)

A complete survey of the whole of Aldabra to show the extent of distribution of Anopheles may help to solve the problem as to whether *Anopheles gambiae* existed prior to 1908 or is only of recent introduction.

It may be mentioned that apart from its geological formation which is conducive to the formation of breeding pools over extensive areas, Aldabra has a rich fauna of birds, giant tortoises and wild goats, factors which would contribute to the spread of this Anopheles all over the atoll.

Action proposed to be taken by Government.

On the recommendation of the Government Medical Department, legislation has been promulgated and put into force.

1. To prevent the introduction of the Anopheles into Mahé, vessels coming from Assumption and Aldabra have to anchor in the outer harbour, at least one mile from land, and be fumigated with sulphur before entering the inner harbour.

2. To prevent the introduction of the Anopheles into the other islands, vessels from Assumption and Aldabra proceeding to other islands must call at Mahé to be fumigated before proceeding to destination.

3. As far as the infected islands are concerned, to start with Aldabra where the Anopheles has been discovered, the recommendation of the Medical Department (1931) is to evacuate all the labourers for a period of three months and thereafter not allow on the island any person who has lived in a malarial country or who has contracted the disease, a very sweeping recommendation which is bound to prove difficult in practice and also make it impossible to obtain sufficient labour for these islands. Only a certain section of the labour population of Seychelles are accustomed to work on the outlying islands, and the majority of these are constantly changing from one island to another, including Juan de Nova, a malaria infected island off the west coast of Madagascar, whence the plasmodium infecting Aldabra most probably originated.

4. Except for temporary recommendations embodied in Dr. Matthew's report (1931) that the water tanks be protected with wire gauze, and the actual and potential breeding pools be filled in with sand (in itself impracticable economically) or treated with paraffin (also an expensive measure) no further suggestions have been made to the lessees of the island.

It is illuminating here to quote the following extract from the last Annual Report (1929) of the Government Medical Department (written before Anopheles had been discovered at Aldabra):

'*Mosquito and insect-borne diseases.*—The colony is surrounded by malarial countries and the introduction of malaria had to be carefully watched. At Port Victoria all cargo is fumigated with sulphur fumes to destroy any mosquitoes that may be hidden in the cargo and special regulations have been adopted for vessels calling at the outlying island.'

This statement embodies the principle of an excellent measure if sufficient care is taken to apply it in practice.

In actual fact, however, cargo from steamers and other vessels is discharged into lighters and conveyed in these, straight to the customs shed which is situated on the pier connecting it with the town about three hundred yards away. It usually takes about 24 hours to transfer cargo from the lighters into

the shed for fumigation, thus giving 24-hours start to the mosquito to get safely on the island before an attempt is made upon its life.

The fumigation shed itself has open eaves through which the remaining mosquitoes can escape. Further, the lighters tied up against the shed which might well harbour some of the mosquitoes that may have escaped from the cargo during loading, transit and unloading, are not fumigated.

It is fortunate for Mahé that cargo-boats usually anchor about one mile from the end of the pier and cargo during the process of unloading usually receives fairly rough handling sufficient to rid them of most of their mosquito stowaways long before fumigation can be of any use. Fumigation by sulphur has undoubtedly other useful purposes in the disinfection of cargo, but let it be applied in as air-tight a building as possible, and by some method more certain than the mere burning of sulphur.

Is this Anopheles the actual carrier at Aldabra?

So far only *Anopheles gambiae* (*costalis*) has been found to exist in the island and it is known to be a renowned carrier of malaria throughout the Ethiopian region.

For the investigation of natural infection it was impossible to obtain mosquitoes in the fresh condition for dissection, an experiment which must be carried out in Aldabra itself. Nevertheless, seven of the available females Mr. Morel succeeded in catching were blocked in paraffin and subjected to serial sectioning in the hope that luck might have placed an infected one among this small number, but in no case were found either sporocysts on the stomach or sporozoites in the salivary glands.

No transmission experiments have so far been carried out.

Description of the Anopheles from Aldabra.

Both males and females are light brown in colour with an average body length of five millimetres. The femora and tibiae are speckled with white spots and bear narrow but distinct pale yellow bands at the articulations of the tarsal joints. The wings show four dark areas covering the costa and first vein. There are patches of dark scales at the distal ends of veins 2 2 to 6, while the fringe shows pale areas at the terminations of these veins. Palps are white tipped with two narrow white bands. The male hypopygia carry a few scales on the external surface of the side-pieces near their attachment to the last abdominal segment and four basal hairs in the usual situation at about the same level. The cercae of the female are ornamented with dark scales.

The fresh larvae are pale brown in colour, turning pale green when fixed in Bles fluid. The fourth stage larva has the external clypeal hairs simple and unbranched. The palmate hairs are extremely pale almost transparent, and

are best seen in reflected light. The combs are composed of more or less regular fine teeth, the majority bearing tiny spines.

The type specimens have been forwarded to Col. Sir S. R. Christophers, at the Central Research Institute, Kasauli, India.

Summary.

The Seychelles Islands have always been free from Anopheles and accordingly from endemic malaria, a fact which has undoubtedly contributed to their healthiness.

The Aldabra group of islands, dependencies of Seychelles, up to 1908 had not been the seat of endemic malaria, while up to 1930 no Anopheles had been discovered on them. Now at least two of these islands are known to be infected with *Anopheles gambiae (costalis)* which is one of the most renowned transmitters of malaria in Africa, Madagascar and Mauritius, where it is responsible for great economic loss.

The danger of the introduction of this species into Seychelles is a real one and great care is demanded in opposing its introduction here. As I have already stated the colony is poor and the introduction of Anopheles might achieve its utter ruin. In addition, Seychelles, for the last few years, has been making attempts to become a holiday and health resort for people from India and East Africa, especially for sufferers from malaria, whose surest safeguard of cure is to get away from the endemic area in which they are constantly getting reinfected. For this purpose Seychelles is an ideal place which is not generally recognized in those countries surrounding it, and it is essential in the event of this recognition materializing, that it should remain malaria free.

Fumigation of ships is useful to prevent the introduction of the Anopheles into the other islands so long as the Anopheles exist on the infested islands.

Fumigation of cargo, from whatever point of view it is done, should be carried out in as air-tight a building as possible. As it takes 24 hours, however, to discharge cargo into the existing disinfection shed, which besides is situated too near the town, the fumigation should be carried out in the lighters themselves at sea, in the outer harbour. This would at the same time ensure the disinfection of the lighters themselves which under the present régime receive no attention. There is no reason why these lighters could not be fitted with tightly fitting lids such as those used in closing the holds of ships, and the sulphur fumes applied under pressure from a specially constructed apparatus, such as Clayton's.

The evacuation of the infected islands suggested is presumably to allow all the infected female anopheles to die and thus get rid of the parasite, but this is more complicated than it looks. The life of a female Anopheles is undoubtedly limited but this has never been determined absolutely in nature. A period of three months is very probably not sufficient. Evacuation of Aldabra

for this purpose would have to be done just before the end of the aestivation period so that any infected female, coming back to active life unconsciously anxious for a definitive host for its sporozoites, would fail to find such and die before this would be available. This entails the determination of the time of year at which aestivation takes place and the length of the period of aestivation. There would probably be great variations, *cf.* Epidemic of 1908 (May to September) and that of 1930 (October to January).

It would be impossible to guarantee any individual free from malaria merely by blood examination. The only possible guarantee would be continual residence in a non-endemic area since birth, or in the case of persons with a history of malaria, residence for at least four or five years in a non-endemic area, without a recurrence of the disease during that period.

The measure that really matters, however, is a practical campaign against the mosquito on the infected islands themselves, especially as the colonizing of Aldabra has been under consideration. This naturally implicates questions of economic importance and advice should be sought from competent authorities. In the first place it is imperative to have a survey made of both islands in their entirety, to determine the extent of spread of the Anopheles. For instance at Aldabra only Picard may be infested with the Anopheles, in which case a campaign would be reduced to its minimum. In the second place, the biology of the existing Anopheles must be studied carefully before the determination of measures to be adopted for its annihilation.

As a larvicide one of the cheapest and most efficient preparations to bear in mind is paris green, which would probably be extremely suitable for the stagnant pools in which breeding goes on in Aldabra.

My thanks are due to Col. Sir S R. Christophers for controlling the technical part of this paper before it went into press and to Mr. Armand Morel du Boil for his careful work in collecting and preparing the necessary specimens at Aldabra, taking observations on the spot and photographs of the breeding places, and for his help generally in the laboratory. I also wish to thank Captain C. C. Thomas, Secretary to the Governor of Seychelles, for his kindness in obtaining for my perusal the reports of Doctors Addison and Power.

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POWER, M. S. (1908) .. .. *Ibid.*
FRYER, J. C. F. (1910) .. .. *Geograph. Jour.*, **37**, 3, p. 261.
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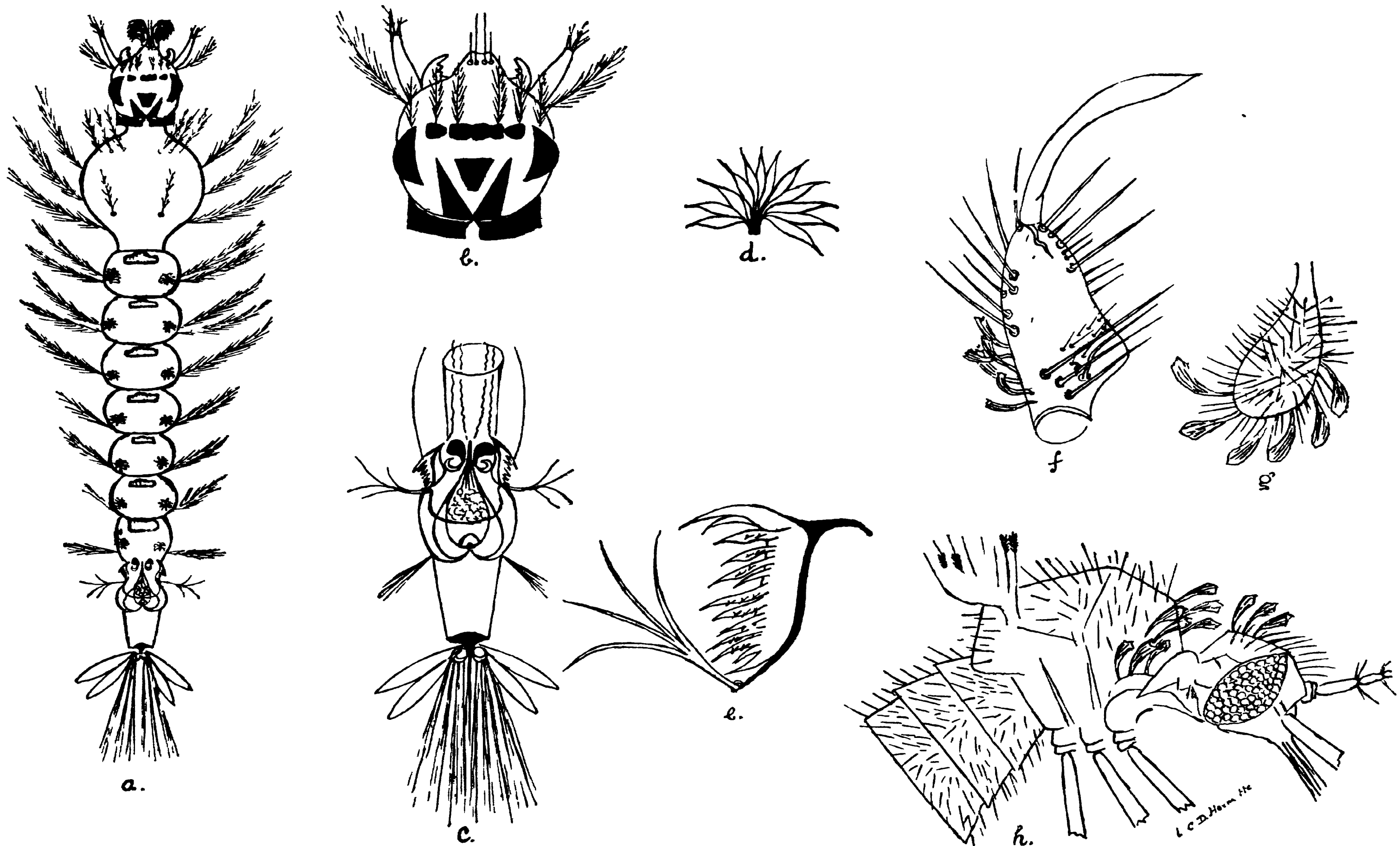
MEDICAL DEPT., SEYCHELLES (1931). Letter accompanying Dr. Matthew's report.

PLATE I

Photograph of *Anopheles gambiae* (*costalis*) breeding pools at Picard Island, Aldabra. *Pemphis* jungle has been cut down to expose the rocky pits

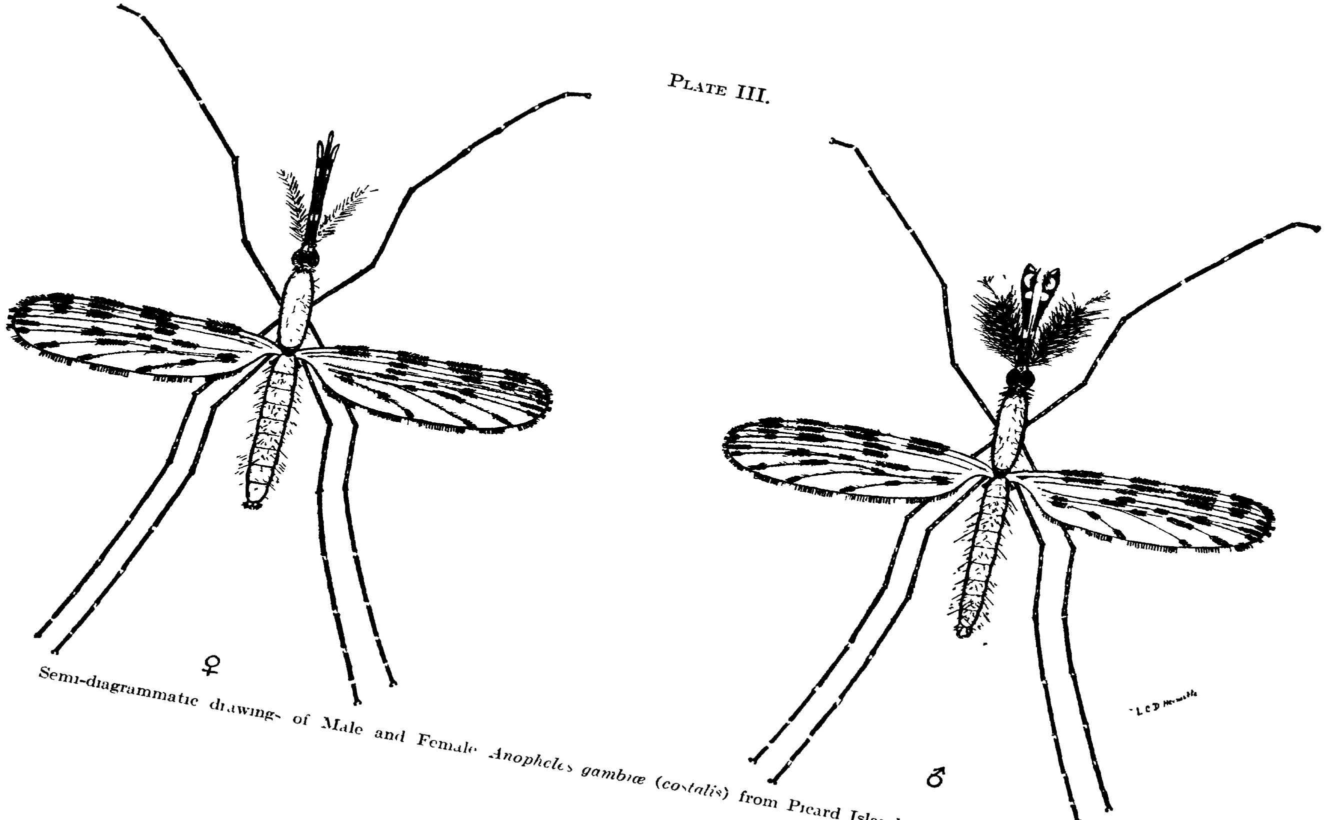
Two pits from the collection in above figure enlarged

PLATE II.



(*a*) Larva at the 4th instar. (*b*) Head of same Larva showing clypeal hairs (*c*) Posterior end of same Larva showing structure of siphon (*d*) Palmate hair of Larva (*e*) Larval comb (*f*) Male hypopygium (*g*) Female cerca (*h*) Drawing of cleared specimen of imago showing distribution of scales on occiput and prothoracic border

PLATE III.



Semi-diagrammatic drawings of Male and Female *Anopheles gambiæ* (*costalis*) from Picard Island, Aldabra

Records of the Malaria Survey of India, Vol. II, No. 4, December, 1931.

DISSECTIONS OF FEMALE ANOPHELINES IN MYSORE STATE.*

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[July 3, 1931.]

DURING the latter part of 1928 and early 1929 three stations for the study and experimental control of malaria were started in the State of Mysore. The first of these stations was opened at Nagenhalli, about three miles from Mysore city; the second was at Mudigere in the Kadur district coffee planting area; the third at Hiriyur in the Chitaldrug district. In addition to dissections made as a routine in these three stations, there are also reported here certain dissections done in the course of the study of epidemics of malaria at the Hulikere Tunnel Works, Mysore district, in Mysore city itself, and at Kamadanahalli village in the Kolar district.

Collections of adult anopheline mosquitoes were made bi-weekly in the regular stations in certain definite catching stations. The adults so caught were transferred to small lamp chimneys and kept in the usual way for at least 60 hours, but more often a full 72 hours. Dissections were done by the staff of the station, all examinations of stomachs and glands being made by the officer-in-charge. Infections reported were checked by one of the writers before being accepted as such when neither of us was present during the dissection and examination. Infections reported in 56 mosquitoes of various species were not considered as properly established.

* The studies here reported were carried out under the auspices of the Government of Mysore and the International Health Division of the Rockefeller Foundation. From the Bureau of Epidemiology and Communicable Diseases of the Mysore Department of Health.

TABLE I.

Dissections of female anophelines in Mysore State between October 1, 1928 and December 31, 1930.

Species.	Routine examinations in three stations.			Examinations during epidemics of malaria.									Grand Total.					
				Hulikere tunnel, October, 1929.			Kolar district village, June, 1930.			Mysore city, August, 1930.			Mosquitoes.		Guts.		Glands.	
	Number of mosquitoes dissected.	Number of guts examined.	Number of glands examined.	Mosq. exam.	Guts inf.	Glds. inf.	Mosq. exam.	Guts inf.	Glds. inf.	Mosq. exam.	Guts inf.	Glds. inf.	Exam.	Inf.	Exam.	Inf.	Exam.	Inf.
A. aconitus ..	1,224	1,221	1,215	..	..	..	..	..	..	..	..	..	1,224	..	1,221	..	1,215	..
A. barbirostris	72	72	72	..	..	..	..	..	..	..	..	..	72	..	72	..	72	..
A. culicifacies ..	5,732	5,687(*b*)	5,619(*c*)	2	..	2	4	..	2	10	..	1	5,748	8	5,703	1	5,635	7
A. fuliginosus ..	788	781	779	..	..	..	..	..	..	..	..	..	788	..	781	..	779	..
A. hyrcanus var. *nigerrimus*.	223	223	222	..	..	..	..	..	..	..	..	..	223	..	223	..	222	..
A. jamesii ..	487	486	483	..	..	..	..	..	..	..	..	..	487	..	486	..	483	..
A. jeyporiensis	6.377	6,317	6,110	..	..	..	..	..	..	..	..	..	6,377	..	6,317	..	6,110	..
A. karwari ..	61	61	61	..	..	..	..	..	..	..	..	..	61	..	61	..	61	..
A. leucosphyrus	3	3	3	..	..	..	..	..	..	..	..	..	3	..	3	..	3	..
A. listonii(*a*) ..	6,034	5,978	5,928(*d*)	..	..	..	..	..	..	..	..	..	6,034	1	5,978	..	5,928	1
A. majidii ..	1	1	1	..	..	..	..	..	..	..	..	..	1	..	1	..	1	..
A. maculipalpis var. *indiensis*.	43	43	43	..	..	..	..	..	..	..	..	..	43	..	43	..	43	..
A. pallidus ..	137	137	135	..	..	..	..	..	..	..	..	..	137	..	137	..	135	..
A. philippinensis	24	23	24	..	..	..	..	..	..	..	..	..	24	..	23	..	24	..
A. stephensi ..	2.708	2,683(*e*)	2,646	1	..	..	..	..	..	1	..	..	2,710	2	2,685	2	2,648	..
A. subpictus ..	5,961	5,906	5,866	7	..	..	11	..	..	1	..	..	5,980	..	5,925	..	5,885	..
A. tessellatus ..	220	216	214	..	..	..	..	..	..	..	..	..	220	..	216	..	214	..
A. turkhudi ..	10	10	10	..	..	..	..	..	..	..	..	..	10	..	10	..	10	..
A. vagus ..	1,135	1,127	1,125	..	..	..	..	..	..	..	..	..	1,135	..	1,127	..	1,125	..
All anophelines	31,240	30,975	30,556	10	..	2	15	..	2	12	..	1	31,277	11	31,012	3	30,593	8

(*a*) *A. listonii* includes *A. minimus* and *A. minimus* var. *varuna*.

(*b*) One *culicifacies* stomach found infected out of 135 *culicifacies* dissected and 135 stomachs examined at Nagenhalli, Mysore district, in April, 1929.

(*c*) One *culicifacies* gland found infected at same place in same month out of 134 glands examined from 135 *culicifacies* dissected.
One *culicifacies* gland found infected at same place in August, 1929, out of 482 glands examined from 505 *culicifacies* dissected.

(*d*) One *listonii* gland found infected at same place in April, 1929, out of 38 glands examined from 39 *listonii* dissected.

(*e*) Two *stephensi* stomachs found infected at Hiriyur, Chitaldrug district, out of 42 stomachs examined from 48 *stephensi* dissected in September,

Table I gives the figures for dissections of the anophelines and examinations of guts and glands. The table is divided into two portions, one for the routine examinations at the three stations and the other for certain extra examinations made in places ordinarily fairly free of malaria, but which reported epidemics during the period under survey. This was done so as to bring out better the great difference in infection rates found in dissections of anophelines from the hyperendemic areas in which the three stations were located and those from epidemic areas. The footnotes to the table give the essential information as to infections found during the routine examinations. It should probably be mentioned that the great majority of the *A. stephensi* caught were not bred in wells or around houses but in marshy areas adjacent to the small town of Hiriyur.

A study of other aspects of the work of the stations is being made, and more complete descriptions of the areas concerned and the malaria conditions obtaining will then be given. Since a part of the work here reported has appeared in the quarterly reports of the Mysore Department of Health, it was thought best to present the complete record at this time.

INDEX OF AUTHORS.

INDEX OF SUBJECTS.